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CARRIER BASED AIR LOGISTICS STUDY: INTEGRATED SUMMARY.(U)

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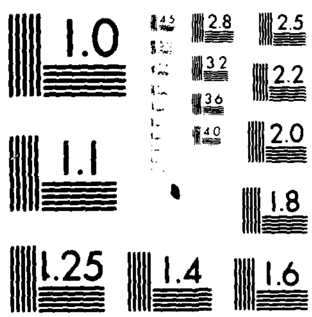

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Carrier Based Air Logistics Study

Integrated Summary

T. F. Lippiatt, R. J. Hillestad, L. B. Embry, J. Schank

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The Carrier Based Air Logistics Study (CABAL) was conducted to examine alternative logistics support policies for avionics equipment with respect to their potential to improve aircraft availabiltiy and performance in wartime. The study considers the entire logistics support system and the interaction of its various functions and resources, through a detailed examination of expected avionics suite availability under alternative logistics structures and policies. It deals with six aircraft types included in most carrier deckloads--the F-14A, S-3A, E-2C, and three A-6 variants. Most of the substantive results presented are based on analysis of avionics suite support for three first three type, model, series of aircraft listed above. 92 pp. Ref.

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Carrier Based Air Logistics Study

Integrated Summary

T. F. Lippiatt, R. J. Hillestad, L. B. Embry, J. Schank

January 1982

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SANTA MONICA, CA. 90406

PREFACE

The Carrier Based Air Logistics (CABAL) study has two primary purposes: (1) to evaluate a specific alternative to the current logistics support structure suggested for further analysis in the Defense Resource Management Study (DRMS) report to the Secretary of Defense (February 1979) and (2) to identify and evaluate potential improvements in the current logistics support structure that could enhance aircraft availability during wartime without the complete structural change required by the DRMS alternative.

The study considers avionics components utilized by six aircraft types that are included in most carrier deckloads--the F-14A, S-3A, E-2C, and three A-6 variants. It focuses on key logistics elements that support carrier aircraft, including the supply system, shipboard component repair facilities (including test equipment), maintenance manpower for those facilities, and transportation for the resupply of components not reparable aboard ship and the return of components to be repaired at depot facilities. Two key elements of the DRMS recommendation--the proposals to consolidate squadrons of the like-type aircraft and to establish a responsive transportation system--were considered in separate studies by the Center for Naval Analyses (CNA).

Changes suggested in this study are directed toward improving the readiness and availability of carrier based aircraft rather than toward reducing cost. Most recommendations suggest implementation rather than further study. In those cases that warrant further study, the Navy either is already performing such analysis or has an in-house capability for doing so.

This report was prepared as an integrating document for readers primarily concerned with findings and recommendations. As such, it omits many of the details of the analysis and attempts to provide the findings, the logic behind the results, and illustrations of the analysis. Three companion documents describe the analysis in more detail:

CABAL Supply and Transportation Analysis [Ref. 3]

CABAL Data Sources and Issues [Ref. 1]

CABAL Maintenance Analysis [Ref. 7]

This work was sponsored by the Office of the Chief of Naval Operations (OP-51).

SUMMARY

The Carrier Based Air Logistics Study (CABAL) was conducted to examine alternative logistics support policies for avionics equipment with respect to their potential to improve aircraft availability and performance in wartime. Toward this end, its objectives were to: (1) evaluate a specific alternative to the current logistics support structure identified for further analysis in the Defense Resource Management Study (DRMS) and (2) identify and evaluate potential improvements in the current logistics support structure that could enhance wartime aircraft availability without the complete structural change implied by the DRMS alternative. The study was to consider the entire logistics support system and the interaction of its various functions and resources, through a detailed examination of expected avionics suite availability under alternative logistics structures and policies. It dealt with six aircraft types included in most carrier deckloads--the F-14A, S-3A, E-2C, and three A-6 variants. Most of the substantive results presented here are based on analysis of avionics suite support for the first three type, model, series (TMS) of aircraft listed above.

BACKGROUND

The Defense Resource Management Study (DRMS) [Ref. 11] included a preliminary analysis of carrier based air logistics support as part of its investigation of logistics support alternatives for a variety of combat weapon systems. The study suggested that low peacetime aircraft

availability was a major problem and identified alternative policies which might improve both peacetime readiness and wartime operational performance.

The DRMS suggested that the relatively small size of carrier squadrons (combined with existing stockage, maintenance manpower, and test equipment requirements policies) was a primary cause of the aircraft availability problem. For each carrier the logistics system has to support seven to eight different aircraft types assigned to nine to ten squadrons, each having a small number of aircraft--as few as four and as many as 12.

Small aircraft populations mean small scale in logistics operations. A number of areas were identified in which the relatively small scale, coupled with resource requirement policies, might have an adverse effect on logistics support. With a demand-based stockage policy, the quantity of on board spares is limited by the low demand generated by the small numbers of each type of aircraft, making it difficult to stock the extremely wide range of parts that could be required to repair aircraft components. This limited range of on board repair parts can result in long awaiting parts (AWP) time, thus slowing the component repair process.

Test equipment requirement policies differ from those for providing spare parts. Typically, test equipment is provided if there is demand for on board repair. Thus, the range of aircraft that must be supported drives the requirements for many different types of test equipment. Because most equipment is highly specialized and testing demands are low, test equipment utilization tends to be very low. This, coupled

with the demand-based stockage policy, make it difficult to stock the range of test equipment repair parts that might be required. It is also difficult to provide the necessary maintenance skills and calibration equipment because of the diverse range of equipment to be supported.

A similar problem exists in the requirements for manpower. The manpower requirement for intermediate level repair personnel assigned to each squadron is based on each squadron's workload spread across numerous naval enlisted classifications (NECs). If there is a repair requirement, no matter how small the projected workload, a billet is required. Again, because of the small size of each squadron, many of these personnel have small workloads and low utilization.

The DRMS recommended further investigation and evaluation of a logistics support alternative that would move some intermediate level repair from the carrier to shore-based Aircraft Intermediate Maintenance Departments (AIMDs). This would increase the scale of repair by consolidating the requirements for manpower, test equipment, and repair parts at fewer locations. The hypothesis was that this alternative would result in (1) reduced manpower requirements, the savings from which could be used to provide additional spare components on board the carrier or improved transportation; (2) reduced AWP time; and (3) improved test equipment utilization and availability. The results also suggested that a reduction in AWP time and improved test equipment availability would reduce repair times.

In addition to suggesting that some of the component repair could be moved to shore-based facilities, the DRMS recommended that a more responsive transportation system be investigated since it would benefit

both the shore repair alternative and the current support structure. It recommended that utilization of manpower could be improved by cross training (creating billets with dual NECs) and by using the scale of the total AIMD workload to determine manning requirements (rather than segmenting workload by squadron and aircraft type).

A key task of the CABAL study was to fully evaluate the DRMS findings using more complete and more recent data. In addition to examining the DRMS recommendations, including the shore repair alternative, the CABAL study was to identify and evaluate other options which might improve the performance of the current logistics support structure.

The study's findings on the DRMS proposal are summarized below. The CABAL study also identified a number of recommended changes in current logistics policies and procedures. They are presented in the Conclusions and Recommendations chapter of this summary report.

CABAL CONCLUSIONS ON THE DRMS SHORE REPAIR ALTERNATIVE

The CABAL analysis indicated that the DRMS shore repair alternative, in general, is not currently attractive. Implementing other DRMS recommendations to dual-code NECs and to consider the total wartime AIMD workload when establishing manpower requirements would yield utilization rates exceeding 90 percent for all avionics work centers. Thus, no manpower savings would be generated by moving repair ashore--savings which, in turn, could be invested in additional shipboard supply stocks or improved transportation. Furthermore, the maintenance management analysis showed that local priority repair

potentially provided the flexibility to dramatically shorten repair times for critical components and compensate for short-term resource shortages. This flexibility would be severely limited or lost under the DRMS shore repair alternative.

The supply analysis showed that the policy of providing additives to the demand-based Aviation Consolidated Allowance List (AVCAL) stockage increased the range of low demand components and repair parts at a relatively low cost. This policy, combined with shop replaceable assembly (SRA) cannibalization, significantly reduced AWP problems; thus, moving repair ashore to consolidate the demand for repair parts would not improve AWP time enough to offset the long transportation pipeline.[1] As noted above, there were no manpower savings to offset the additional transportation pipeline stockage costs. The supply analysis also showed that using an aircraft availability objective rather than a requisition "fill rate" criterion for establishing stock levels significantly improved performance without cost increases.

The test equipment analysis, on the other hand, showed that the Versatile Avionics Shop Test (VAST) work center could not support the workload generated by a sustained wartime flying program. One alternative to alleviate the wartime backlog would be to move all VAST SRA repair to other shipboard equipment where it is technically feasible. Another would be to move SRA repair to shore-based facilities

[1]The CABAL transportation analysis was performed by the Center for Naval Analyses (CNA). CNA's work indicated that retrograde times average about 65 days and order and shipping times about 25 days; it did not identify the reasons for these inordinately long transportation times or identify options for reducing them. The CNA transportation results were used in the work reported here in conformance with the Navy task order [Ref. 8].

with excess capacity in wartime. A combination of both options is likely to be the least expensive. The test equipment analysis also showed that most test equipment had low utilization, but because the current equipment inventory represents a sunk cost little near-term savings would be generated by consolidating repair ashore. Decisions about future system test equipment requirements should consider the shore repair option; it may be cost effective.

Therefore, based on the CABAL analysis, the shore repair alternative does not look promising for most components used on current aircraft. Thus it is not recommended that the shore repair alternative be tested at this time.

The shore repair alternative should, however, be considered for the wartime VAST backlog and future test equipment requirements. In both cases, for a given level of aircraft performance, the costs of supporting shipboard repair may exceed those of providing for repair ashore.

ACKNOWLEDGMENTS

The CABAL study could not have been performed without excellent cooperation from the U.S. Navy. Admiral P. H. Speer (OP-05B) and the entire Navy Advisory Board provided useful advice and criticism which contributed to the balance and credibility of the analysis. The study benefited immensely from the many helpful comments and criticisms of Admiral R. W. Carius (OP-51) and his staff. Captain Charles Bolinger and his assistant, Lt. Commander Stan Hunter, were instrumental in steering us to the right agencies and persons for data acquisition, orientation, and expert opinion. Without exception, Navy personnel at all levels were frank, open, and cooperative in their interactions with the CABAL study group.

We wish to thank Frank Swofford of the Navy Secretariat for his encouragement and support throughout the study. Rand staff members Brent Bradley and Robert Paulson reviewed the CABAL publications; their comments and criticisms added immeasurably to the quality of this report. Patricia Konoske Dey and Gail Halverson provided computer support. Our special thanks to our secretary, Dee Saenz, for keeping the administrative details of trips, meetings, and paperwork from completely engulfing us. Thanks also to Dee and Suzi Jackson for their support in the final documentation.

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FIGURES

TABLES

GLOSSARY

3M	Maintenance and Material Management Systems
AECL	Avionic Equipment Configuration List
AIMD	Aircraft Intermediate Maintenance Department
ASO	Aviation Supply Office
ASW	Antisubmarine Warfare
AVCAL	Aviation Consolidated Allowance List
AWP	Awaiting Parts
BCM	Beyond the Capability of Maintenance
CABAL	Carrier Based Air Logistics Study
CANN	Cannibalization
CATS	Computer Aided Test Set
CNA	Center for Naval Analyses
COMM	Communications
CV	Carrier
DRMS	Defense Resource Management Study
Dyna-METRIC	Dynamic Multi-Echelon Technique for Reparable Item Control
ELEC	Electrical
EXREP	Expedited Repair
FMC	Fully Mission Capable
FMCA	Fully Mission Capable for Avionics
HATS	Hybrid Automated Test Set
I-Level	Intermediate Level
IMA	Intermediate Maintenance Activities
INS	Inertial Navigation System

INST	Instruments
LOR	Level of Repair
MOD	Module
NALCOMIS	Naval Aviation Logistics Command Management Information System
NARF	Naval Air Rework Facility
NAS	Naval Air Station
NATO	North Atlantic Treaty Organization
NAVMMACLANT	Navy Manpower and Material Analysis Center, Atlantic
NAV	Navigation
NEC	Naval Enlisted Classification
NMC	Non Mission Capable
NMCM	Non Mission Capable--Maintenance
NMCS	Non Mission Capable--Supply
O-Level	Organizational Level
O&ST	Order and Ship Time
PMC	Partially Mission Capable
POE	Projected Operational Environment
RIMSTOP	Retail Inventory Management Stockage Policy
ROC	Requirement for Operational Capability
SACE	Semi-Automatic Checkout Equipment
SAVAST	Ships AVCAL Asset Demand Tape
SCIR	Subsystem Capability Impact Report
SQMD	Squadron Manning Document
SRA	Shop Replaceable Assembly
TAD	Temporary Additional Duty

TYCOM	Type Commander
VAST	Versatile Avionics Shop Test
VSL	Variable Safety Level
WRA	Weapon Replaceable Assembly

I. INTRODUCTION

The Carrier Based Air Logistics (CABAL) study examined alternative logistics policies and structures for support of avionics equipments installed on six aircraft included in most aircraft carrier deckloads--the E-2C, F-14A, S-3A, and three A-6 variants. Because of their high cost and their criticality in likely future combat scenarios, the study focused on the support of avionics equipment. It considered the entire logistics support system for component repair and the interaction of its various elements, including maintenance, supply, and transportation. Although all echelons of the support system play a role in supporting aircraft avionics, the intermediate level of support has a direct effect on aircraft availability and wartime performance capability. Hence most of the analysis of policy options centered on what has traditionally been the shipboard level of support.

BACKGROUND

The Defense Resource Management Study (DRMS) [Ref. 11] included a preliminary analysis of carrier based air logistics support as part of an investigation of logistics support alternatives for a variety of combat weapon systems. The results suggested that low peacetime aircraft availability was a major problem and presented preliminary analyses to identify alternative policies that could improve both peacetime readiness and wartime operational performance.

The DRMS suggested that the small size of carrier squadrons was a primary cause of low aircraft availability. For each carrier the

logistics system must support seven to eight different aircraft types assigned to nine or ten squadrons, each having a small number of aircraft--as few as four and as many as twelve.

Small units and low aircraft populations mean small scale in logistics operations. Lack of scale can adversely affect combat capability by limiting the range of resources for which requirements are stated (as in the case of spare parts), or by providing range in some resources at the expense of depth in others. The DRMS identified those areas in which small scale might adversely affect logistics requirements, resource utilization, and support delivery performance: spares, test equipment, and maintenance manpower.

With the current demand-based stockage policy, the range of spares carried in support of small populations of aircraft will be small since relatively few components have expected demands that exceed the threshold value required to qualify them for stockage. This is particularly true for the indentured components needed to effect repairs on Weapon Replaceable Assemblies (WRAs) exchanged at the flight line. Because many low demand component repair parts do not qualify for stockage under the demand-based criteria, component repair could be delayed while the repairing work center awaits delivery of needed parts (AWP) that are not stocked on board. This also reduces carrier self-sufficiency, since it is then dependent on transportation to deliver non-stocked components.

Test equipment requirement policies differ from those for spare parts. Typically, test equipment is provided if there is an expected demand for on board repair. Thus the range of aircraft that must be

supported on a carrier drives requirements for many different types of test equipment. Because most equipment is specialized and testing demands are low, test equipment utilization tends to be very low. With low utilization, the demands for most test equipment repair parts are low, and under the demand-based stockage policy a limited range of repair parts qualify for on board stockage. As a result, a failure can cause significant test equipment downtime awaiting parts, queuing of maintenance workloads, and ultimately degraded aircraft availability. Also, it is difficult to provide the necessary maintenance skills and calibration equipment because of the diverse range of equipment to be supported.

A similar problem exists in the requirements for manpower. The manpower requirement for intermediate level component repair personnel assigned to each squadron is based on each squadron's workload spread across numerous naval enlisted classifications (NECs). These personnel are assigned to the Aviation Intermediate Maintenance Department (AIMD) as temporary additional duty (TAD) when on board or at home station. Again, because of the small size of each squadron, many of these personnel have small peacetime workloads and low utilization.

Based on a limited analysis of these issues, the DRMS recommended further investigation and evaluation of a logistics support alternative that would move some intermediate level repair from the carrier to shore based AIMDs. This would increase the scale of repair by consolidating the requirements for maintenance manpower, test equipment, and repair parts at fewer locations, and would result in (1) reduced manpower requirements, the savings from which could be used to provide additional

spare components on board the carrier or improved transportation; (2) reduced awaiting parts time; and (3) improved test equipment utilization and availability. The study also suggested that the reduction in AWP and improved test equipment availability would reduce repair times. These maintenance and supply performance improvements were expected to improve overall spare parts availability on the carrier, and hence operational performance.

The DRMS also recommended (1) investigation of a more responsive transportation system since it would benefit both the shore repair alternative and the current support structure, (2) improved utilization of manpower by cross training (creating billets with dual NECs) and by using the scale of the total AIMD workload to determine manning requirements (rather than segmenting workload by squadron and aircraft type), and (3) consideration of managing intermediate level repair personnel at the AIMD rather than in individual squadrons.

CABAL STUDY OBJECTIVES

The primary purpose of the CABAL study, like that of the DRMS, was to identify and examine alternative logistics support policies that would improve wartime aircraft availability and operational performance [Ref. 8]. A key task of the study was to evaluate the DRMS findings using more complete and more recent data. In addition to examining the DRMS recommendations, including the shore repair alternative, the CABAL study was to identify and evaluate other options which might improve the performance of the current logistics support structure. If such options did show promise, they might be preferable to the shore repair

alternative. This investigation was to be based on a cross-functional analysis of the interdependent elements of the logistics support system. It was also to consider the implementation issues raised by recommendations for improving wartime aircraft availability.

CABAL CONTEXT

Carrier Flight Operations

The striking power and defensive capabilities of a modern carrier are concentrated in a heterogeneous deckload of aircraft configured for a variety of missions. This deckload, which is limited by flight and hanger deck space constraints, typically includes over 80 aircraft, distributed as shown in Table I-1.

Most carrier flight operations are conducted on a cyclical schedule. Each cycle begins with the launch of 17 to 21 aircraft,

Table I-1

TYPICAL CARRIER DECKLOAD FOR A MODERN ATTACK CARRIER (CV)

Aircraft	Type	Squadrons	Aircraft per Squadron	Total Aircraft
F-14A	Fighter	2	12	24
A-7E	Light Attack	2	12	24
A-6E	Attack	1	10	10
KA-6D	Tanker	1	4	4
S-3A	ASW	1	10	10
E-2C	Surveillance	1	4	4
EA-6B	Electronic Warfare	1	4	4
SH-3	ASW	1	6	6
Total		9	4-12	86

followed by recovery of those launched on the previous cycle. A combat flying day includes approximately seven of these cycles, each lasting about two hours, during which 120 to 140 sorties of various types are launched. War plans contemplate round-the-clock antisubmarine warfare (ASW) operations, but personnel considerations (primarily crew fatigue) constrain sustained wartime operations for the other aircraft to the seven-cycle day.

The carrier based air logistics system supports the carrier's flight operations by maintaining the material readiness of the carrier air wing. Although each function in the logistics system has its own measures of performance, in this context the ultimate performance measure is sortie generation capability. A close proxy for this "ultimate" measure is wartime aircraft availability; the logistics system's function is to minimize non-availability due to shortages of needed logistics resources.

The Aircraft Material Readiness Support System

Aircraft material readiness, or the availability of mission-capable aircraft to meet operational commitments, is determined by:

- The "break rate," or frequency with which failed subsystems must be repaired.
- Organizational level maintenance performance in fault isolation and component replacement.[1]

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[1]Flight line maintenance is a critical determinant of aircraft material readiness. A mechanic's failure to identify the problem component may place unnecessary demands on the logistics system, and maintenance queuing may prevent correction of problems even when needed parts are available. The CABAL study focused on intermediate level

- Maintenance policies which establish what maintenance will be performed, when, and by whom.
- The availability of spares to replace "holes" in aircraft created by removal of faulty components.

In the short run, the first three of these determinants of performance establish support requirements that must be addressed by the spares support system. This system, which will determine performance for any fixed specification of the other three, is a function of resource levels and policies employed in a number of interrelated and interdependent functions:

- Communications, for transmittal of material requirements to a source of supply.
- Intermediate and depot level maintenance, to restore failed components to a serviceable condition.
- Transportation, for movement of needed material from a repair or storage location to the point of use.
- Supply, to maintain inventory levels and direct asset distribution in response to material requisitions or requirements forecasts.

The resulting material support process, outlined in Fig. I-1, shows two echelons of inventory that serve as buffers between the three levels of maintenance. The flow of components between these inventory locations, where the aircraft itself can be seen as a third level of

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maintenance, and did not deal directly with organizational level maintenance.

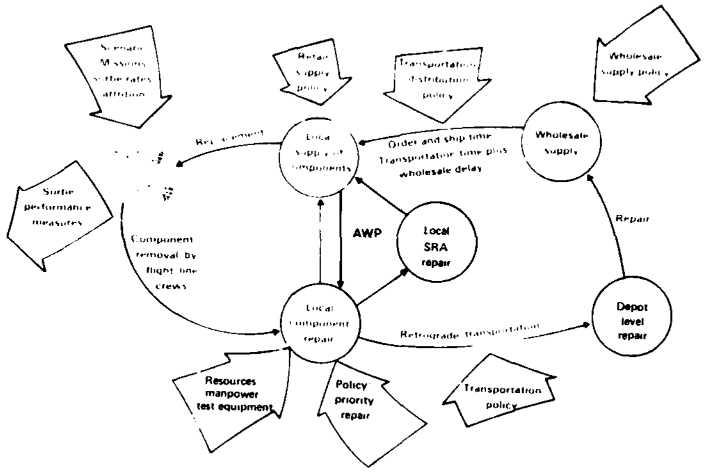

Fig. I-1—Pipeline model of the two-echelon inventory and maintenance system for aircraft component repair

inventory, generates pipeline inventory requirements. Inventory levels must contain sufficient assets to cover these pipeline requirements or a failure on the aircraft will remain as a hole until assets can be generated by the repair or procurement process.

Inventory requirements are affected directly by the contents of the resupply pipelines, which are themselves a function of the rate at which parts are inducted and the time spent in the pipeline once inducted. Conversely, given a level of material assets, supply performance is determined by demand rates, the distribution of assets within the system, and the performance of the communications, maintenance, and transportation functions in delivering serviceable assets to the point of use.

The performance of these functions is influenced by availability of a variety of different resources. For example, intermediate level maintenance pipeline times are affected by on-hand quantities of:

- Manpower with the requisite skill mix (an inventory problem of its own).
- Test equipment.
- Maintenance facilities.
- Parts needed to effect repairs.
- Reparable "carcasses."

The interdependence of these factors demands a cross-functional approach to the material readiness support problem. The analysis and recommendations of this study are based on an analytic approach designed to provide an integrated view of the support process and to focus on the output of that process--aircraft material readiness, measured by aircraft availability, where availability is the percentage of aircraft ready to perform their assigned missions. The study used worldwide component failure and maintenance data covering the period July 1978 through June 1979. Performance was evaluated using analytic models of the logistics support process to project aircraft availability in accepted wartime planning scenarios.

This report summarizes the results of the CABAL analysis. They are reported by function, because functional organizations must take action on individual study recommendations. The following chapter outlines the methodological approach and briefly describes the scenario, data, and

models. Section III addresses the maintenance function, with particular emphasis on maintenance manpower and test equipment. It concludes with a discussion of maintenance management and the need for maintaining an effective interface between the supply and maintenance functions. Chapter IV describes the supply (and related transportation) analysis. Chapter V concludes the report with a summary of findings and recommendations developed through the cross-functional approach to the study. More detailed discussion of the models and analytic results is provided in Refs. 1-4.

II. METHODOLOGICAL APPROACH

The methodological approach employed in the CABAL study consisted of three primary tasks:

- Scenario definition.
- Data base development.
- Modeling and data analysis.

This chapter describes the methodological approach to aid in understanding the analysis and the basis for the recommendations given in Chap. V.

SCENARIO DEVELOPMENT

Most Navy resource requirement methodologies reflect the assumptions of classical failure theory, which associates the failures of aircraft components with aircraft utilization, expressed in flying hours. The CABAL study also assumed this linear relationship between failures (which generate maintenance workload and pipeline stockage requirements) and flying activity. It was therefore necessary to develop a scenario that would generate a flying program consistent with Navy wartime planning as a prerequisite to projection of wartime aircraft availability.

Two scenarios were used in the models described in this chapter:

- A "steady-state" program with level flying activity on each day of a 90-day period.

- A "square wave" program that assumed a 30-day Indian Ocean contingency followed by transition to a NATO war.

These scenarios were based on planning information obtained from the Navy.

Whereas the steady-state scenario does generate programmed flying hours for each of the aircraft considered in the study, it does not contain transients in flying rates that can have a significant effect on maintenance backlogs, repair generations, and supply stockage position. The second scenario, which envisions periods of standdown followed by periods with higher-than-programmed flying activity, generates the same flying hours over a 90-day period as the first but also includes transients in pipeline assets.

In both cases the component removals and demands for resupply are the same when averaged across a time span of about 45 days. The primary difference is that aircraft maintain continuous activity at programmed sortie rates in the steady-state scenario, whereas the dynamic scenario has periods of high activity followed by periods of no activity. In the former case the aircraft must be maintained in a state of high availability at all times, whereas in the latter case the availability needs vary depending on the activity rate. If a set of resources can support the sustained steady-state rates, they should also be able to support the dynamic flying rates. Conclusions drawn from the steady-state scenario were tested in the long-term dynamic scenario.

The effects of an interruption in the resupply pipeline to the carrier were also considered for both scenarios. These excursions permitted evaluation of the protection afforded by the carrier's self-sufficiency stock under a variety of different stockage policies.

The possible effects of combat attrition on the demand for logistics support were not considered because combat losses were assumed to be replaced by "filler" aircraft. Of course, if attrition reduced the total aircraft inventory to the point that filler aircraft were not available, support requirements would be reduced accordingly. In this sense, the scenario generates a conservative (high) estimate of likely demands for support.

THE CABAL DATA BASE

As is common in studies of this type, a great deal of the study effort was devoted to development of a data base describing characteristics of the components to be considered in the analysis. The aircraft were the F-14A, S-3A, E-2C, and three A-6 variants in the deckload described in the Introduction. Since the study was to concentrate on avionics equipments, the set of components was initially based on the Avionics Equipment Configuration List (AECL) for the deckload carried by the USS CONSTELLATION on her 1978 WESTPAC deployment.

When it became apparent that a component list based on the AECL did not include many of the components that generate workload in avionics work centers,[1] the data base was expanded to include these items. Demand and repair data for these components were extracted from 3M reports and the data base was augmented with information on test equipment and skill requirements, depot repair time, and other item characteristics from a number of different sources.

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[1]Workload reported through the Navy's Maintenance and Material Management (3M) system showed other components being repaired in avionics work centers.

The data describe the configuration of aircraft and components, historical removals and BCM (beyond the capability of maintenance) rates, repair times including scheduling, processing, and hands-on repair durations, test equipment requirements, man-hour requirements, and so forth. The 3M failure and repair data used in the study reflect fleet-wide experience for the period 1 July 1978 through 30 June 1979. More recent data were available, but data reporting and processing problems associated with implementation of the new Subsystem Capability Impact Reporting (SCIR) system made these data suspect. Navy representatives advised use of data from the earlier period to minimize data quality problems associated with SCIR implementation.

Component-specific data and indentured[2] relationships between components extracted from the Aviation Supply Office (ASO) weapon system file were used for a variety of statistical analyses to describe peacetime performance of the aircraft material readiness support system. They were also used in conjunction with scenario data for the modeling described below.

MODELS EMPLOYED IN THE STUDY

Three primary models[3] were developed and used in various parts of the analysis:

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[2]"Indentured" relationships describe the application of subcomponents to their next higher assembly, i.e., the set of parts that make up the component exchanged at the aircraft.

[3]A fourth model for generating workloads and manpower requirements as a function of flying activity and logistics support structure was also developed during the study. However, due to a variety of difficulties in obtaining man-hour data consistent with those used in the Navy manpower methodology, this model was not used extensively during the study.

- A model of the logistics support process for evaluating the effects of policy options on measures of wartime aircraft availability.
- A stockage requirement model used to emulate the ASO process for generating Aviation Consolidated Allowance Lists (AVCALs) for carriers and Naval Air stations.
- A queuing model (repair simulation) for evaluating the effects of test equipment and manpower constraints on the component repair process.

Performance Evaluation

A version of Rand's Dyna-METRIC [Refs. 2, 4] model was the primary analytic tool used during the study. This model, an analytic representation of the aircraft support system, avoids four major limitations of current resource requirement methodologies (and most other models of the support system). Dyna-METRIC explicitly:

- Focuses on weapon-oriented performance measures (such as aircraft availability and sortie generation).
- Considers cannibalization[4] as a source of supply.

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[4]Mission-critical demands that cannot be satisfied from stock can be met by cannibalization--the use of parts from systems down for other resources--or by expedited repair of components already in the maintenance pipeline. Traditional measures of supply performance show degradation even when these alternative sources are able to meet the material requirement. The contribution of cannibalization at both the WRA and SRA level to operational performance will be discussed further in Chap. IV.

- Accounts for the transie^ts in support system performance associated with variations in the level and intensity of operations.
- Deals with the interdependencies among resources and functions that characterize the support delivery process.

The model is based on the pipelines concept discussed in the Introduction and uses an extension of Palm's theorem to deal with the stochastic properties of the demand, repair, and resupply processes. In addition, it embodies a capability to examine the effects of resupply or repair interruptions, alternative logistics support structures, claims by more than one aircraft type on a common resource pool, and demand distributions with a variance to mean ratio greater than one (compound Poisson processes).

Figure II-1 shows the various parts of the logistics structure considered within the Dyna-METRIC model. Local repair and resupply of aircraft components [weapon replaceable assemblies (WRAs)] for the flight line are modeled in detail. Scenario driven missions and sortie demands, combined with historical rates of component removal at the flight line, provide the basis for component repair requirements in the shipboard AIMD. Removals by the flight line crews also create a demand against the shipboard supply system to provide a serviceable WRA for the aircraft. When the supply system cannot provide the requested spare part the component is backordered, creating a hole in the aircraft. These holes or shortages of WRAs can be consolidated at the aircraft through the process of WRA cannibalization.

Dyna-METRIC was used to show the resulting aircraft availability with and without WRA cannibalization. Thus, the shipboard supply policy (which determines the quantity of spare parts) and the amount of WRA cannibalization (which moderates the effect of shortages on aircraft availability) are two important aspects of shipboard component repair and replacement measured by Dyna-METRIC.

WRA repair may require the repair of one or more SRAs (subcomponents). Repair of SRAs is another aspect of the shipboard AIMDs modeled in Dyna-METRIC. The shop repairing the WRA generates removal of an SRA and at the same time a demand against the supply system for a spare serviceable SRA to replace it. Inability to provide

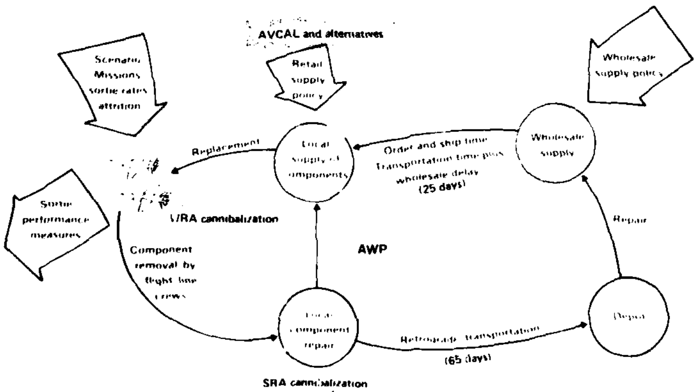

Fig. II-1—The representation of supply and related logistics resources in the Dyna-METRIC model

a spare SRA causes a backorder against that subcomponent and an AWP condition for the WRA. The WRA is then sent to an AWP locker until the appropriate SRA becomes available through SRA repair or resupply. When two or more WRAs are in AWP condition for different SRA backorders, the holes in WRAs can be consolidated by SRA cannibalization. Dyna-METRIC can evaluate SRA supply policy options as well as the effect of SRA cannibalization on AWP and its resulting effect on aircraft availability.

Certain types of repairs cannot be performed at the ship and must depend on retrograde transportation (currently about 65 days) to a depot repair facility. At the time a WRA or SRA is determined to not be reparable aboard ship, an order is placed with the wholesale supply system. When it can ship a component immediately, there is a transportation delay (currently about 25 days) in moving the component to the ship. When the wholesale system cannot provide the component, there is an additional order and ship time (O&ST) delay while the component is backordered. Dyna-METRIC was used to predict the wartime O&ST delay given historical depot repair times and wholesale supply policy for component spares.

Dyna-METRIC requires four classes of input data:

- A scenario that describes the support structure, the flying program by day, and unusual states of the support system, such as transportation cutoff.
- Component data describing the demand rate, maintenance turnaround time, beyond capability of maintenance fraction, resupply time, and characteristics of the demand distribution.

- Resources available to the system, including stock, manpower, and test equipment.
- A description of the relationships among components, and between components and repair resources.

The version of Dyna-METRIC developed for the Navy uses only the first three classes. Due to the size of the study's data base, the fourth class was handled by a series of pre-processors which generate AWP projections for indentured components and for simulating the repair process. As will be discussed in Chap. IV, tests of the models using peacetime flying programs produced results that are quite consistent with the Navy's peacetime experience.

Supply Requirements

Since it is an analytic model, Dyna-METRIC can be used to compute resource requirements to achieve a specified level of operational performance as well as to project performance given a predetermined mix of resources. A separate stockage model was developed during the study, however, because the Navy was concerned that this feature of the model would not accurately reflect current Navy stockage policy. This model approximates the Navy's two-stage AVCAL production process by a single calculation, yielding results that are consistent with those derived from the Navy process.[5]

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[5]ASO has evaluated the AVCAL approximation, and agrees that it fairly represents the current AVCAL production process [Ref. 6].

The generation of the AVCAL requirements for a ship involves a combination of computer processing, negotiations between the Aviation Supply Office and the Fleet, updates based on previous cruise history, and additions to requirements based on the best judgment of the Fleet. Since supply requirements change depending on the logistics support structure and several differently structured AVCALs were required for analysis, it was not possible to use an existing AVCAL constructed for a previous cruise. For practical reasons the AVCAL process was approximated to provide the spare parts requirements for analysis. This approximation used the same set of stockage rules as the Navy AVCAL and the component set described above. The approximated AVCAL and the Navy requirements differed primarily in the specific components affected by negotiations and updates using previous cruise history. The negotiations were not approximated and the approximation of updates used similar rules but was based on worldwide removal data for a one-year period rather than previous cruises.

Comparisons which could be made with the Navy AVCAL indicated that the range and depth rules were correct and that total costs of the avionics equipment in the AVCALs were about the same. The close prediction of AWP discussed in Chap. IV was another comparison of the accuracy of the AVCAL approximation.

Currently, wholesale parts requirements are determined with a variable safety level (VSL) method which gives an 85 percent fill rate averaged across all components. For analysis purposes, the stockage model was used to give each component a spares level to achieve at least an 85 percent fill rate. This causes the average fill rate to be a

little higher than 85 percent but, since the analysis was concerned with repair aboard ship, this was considered accurate enough to reflect the behavior of the wholesale system and the wartime order and ship delays likely in that system <u>when the wholesale spares requirements are fulfilled</u>. The effects of wholesale system shortages were not examined in this study.

The stockage model computes stockage requirements given the demand rate, repair time, BCM rate, and endurance period. The model contains an optimization option which facilitates stockage against an aircraft availability measure rather than a "supply effectiveness," or "fill rate," criterion. The model was used to develop stockage levels for the current system, stockage under a RIMSTOP[6] alternative, and an improved stockage policy; these levels were subsequently evaluated using the Dyna-METRIC model.

Maintenance Queuing

The third primary model was a mean value simulation of the repair process used to evaluate maintenance queuing due to capacity constraints. After generating failures based on component demand rates and the scenario flying program, it schedules repairs based on the stock position and test time requirements of each component. The model employed a scheduling algorithm designed to minimize the number of holes in aircraft created by any one type of part, and demonstrated clearly the value of priority repair [known as expedited repair (EXREP) in the

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[6]Retail Inventory Management Stockage Policy, a DoD program that will change the basis for requirements computation for all of the services [Ref. 12].

Navy] when maintenance capacity has the potential to severely constrain operational performance. The results of the queuing analysis reported in Chap. III show how in the short run maintenance can compensate for shortages of stock, indentured components, test equipment, and/or manpower.

EXPLANATION OF PERFORMANCE MEASURES IN THE ANALYSIS

The study shows the results of policy and resource changes on aircraft availability, which is usually described by the terms PMC, FMC, NMC, NMCS, PMCS, NMCM, and PMCM. PMC is the average number of partially mission capable aircraft at a point in time; it is given with respect to a mission type or mission category and represents the aircraft capable of performing those types of missions. FMC is the average number of aircraft fully mission capable and includes only those aircraft which are capable of performing all missions at a point in time. NMC is the opposite of FMC and therefore includes only those aircraft which are not capable of performing at least one of the required missions. The addition of the suffix S or M indicates that the cause of degraded capability is either supply or maintenance. Aircraft not available for supply reasons are those missing WRAs because of removals and unfulfilled supply requisitions. Those not available for maintenance reasons include aircraft being worked on at the flight line and aircraft undergoing maintenance or periodic inspections on the hanger deck, which may or may not have component holes.

The measures used in this study are modifications of PMC and FMC because the analysis only deals with avionics components. Here we will

use the measures PMCA, FMCA, and NMCA. PMCA is the average number of aircraft available for a given set of missions after aircraft with missing or nonfunctioning avionics are removed, <u>but before loss of capability due to engines, other components, or maintenance is considered</u>. NMCA represents the average number of aircraft which are not capable for any mission because of avionics malfunctions and is therefore the number of aircraft unavailable due to the subset of components considered in this analysis. Finally, FMCA represents those aircraft with a completely functioning avionics suite.

III. AVIONICS MAINTENANCE AND MAINTENANCE MANAGEMENT

The carrier AIMD serves as the primary source of supply for the reparable items required to maintain aircraft avionics suites. For the aircraft considered in the CABAL study, 85 percent of the WRAs removed at the flight line are returned to on board supply stocks. Similarly, 62 percent of the reparable subassemblies removed during repair of higher indentured components are restored to serviceable condition by the AIMD.

Three key resources are used in the intermediate level repair process:

- Maintenance manpower.
- Test equipment.
- Subassemblies and/or consumable parts required to effect repairs.

This chapter focuses on the first two resource categories. In addition, it discusses the roles of maintenance management in integrating different types of resources and establishing repair priorities that are responsive to supply requirements. Results and recommendations emanating from the manpower, test equipment, and maintenance management analyses are summarized in Chap. V.

MANPOWER[1]

Intermediate-level maintenance manpower requirements for Navy aircraft are currently determined through application of the standards contained in ACM-02 [Ref. 10], a manpower methodology developed by the Navy Manpower and Material Analysis Center, Atlantic (NAVMMACLANT). ACM-02 uses historical aircraft maintenance experience, as recorded in the 3M data system, as the basis for determining the number of aircraft maintenance personnel required. The model develops average workload per aircraft values from the worldwide recorded intermediate-level (I-level) work for each type, model, and series of aircraft. The workload per aircraft values are multiplied by the number of aircraft supported by an AIMD and then disaggregated to specific work centers and to specific skill [Naval Enlisted Classification (NEC)] requirements, again based on the workload distribution of historical data. The model deals with manpower at the work center level and calculates requirements by aircraft squadron. By accumulating squadron manpower requirements, ACM-02 determines total manpower for a given AIMD.

Manpower Implications of Repair Alternatives

Two important changes occurred between the time of the DRMS and the CABAL study. The manpower workloads used in the DRMS analysis were based on an earlier version of the ACM-02 model (dated January 13, 1978). The model has since undergone updates of factors and techniques and the current version used in the CABAL study (dated March 30, 1979)

[1]A more detailed explanation of the manpower analysis portion of the CABAL study is contained in Ref. 7.

results in a significant increase in the workload of the avionics work centers. This increase in work, more than 70 percent above the DRMS values, is a result of an increase in both the total measured I-level maintenance workload for each aircraft (termed the B value in ACM-02) and in the proportion of the total work that is attributed to avionics work centers (the Z table in ACM-02).

The cause of the expanded workload is unknown, although a number of factors have probably contributed--better reporting by the AIMDs, better collection by the 3M community, better accounting of total work by ACM-02, and possibly, more component failures and longer repair times.

The second change since the DRMS involves the number of billets required to perform the calculated workload. The more recent implementation of ACM-02 has required the cross training of naval enlisted classifications which have low workload but similar, compatible work within the same shop. This concept was suggested in the DRMS as a partial solution to the low utilization rate problem. This change brought about dual-coded billets and reduced I-level TAD billets 30 percent below the manpower requirements considered in the DRMS.

The increasing workload and decreasing billets have combined to greatly increase the projected utilization of I-level personnel. As personnel utilization increases, the economies of scale to be gained from consolidating repair actions diminish (personnel fully utilized can show no higher utilization in an alternative structure). The potential manpower savings projected during the DRMS are therefore significantly reduced. Furthermore, the wartime utilization of personnel, and ultimately the number of personnel required, may be greater than indicated by the current ACM-02 methodology.

Differences in Peacetime and Wartime Workloads

One potential problem identified during the CABAL manpower analysis is the workload used to determine I-level manpower requirements. The ACM-02 model uses workload recorded in the 3M system as the basis for manpower determination. It is based on an average across all like aircraft of the workload generated by the current peacetime flying program. No provisions are made in the ACM-02 model to escalate this workload to wartime flying rates. The basic assumption is complete independence of workload and flying activity.

The assumption of independence between I-level repair and flying activity is contrary to classic reliability theory and even to the assumptions used by the Navy in other areas of logistics support. For example, ASO assumes a linear relationship between failures and flying hours when determining stockage requirements. Also, organizational level maintenance assumes that flying hours affect both preventive and corrective maintenance workloads when calculating O-level billet requirements.

Since the spares and test equipment portions of the CABAL study use a linear factor based on the flying program in their calculations, the manpower analysis also assumes that workload will increase linearly with flying hours. Although workload may not have a precise linear relationship with flying hours, an increase in flying activity will almost certainly generate an increase in maintenance workload. The linearity assumption is conservative; it was used to maintain

consistency in the study and allow comparisons between the existing structure and the proposed alternatives to be measured on a common basis.

The original ACM-02 workloads were so small that the peacetime/wartime question was not an issue. When a billet has a very low utilization, doubling or even tripling the work will not affect billet requirements. However, as has been mentioned, the ACM-02 workloads have substantially increased, thereby increasing personnel utilization. If the workload does vary with the flying program, in war shortfalls may occur. The ACM-02 independence assumption may lead to requirements that understate wartime needs.

As an exercise to determine TAD wartime requirements, the deckload of the CONSTELLATION was chosen as a base case and the TAD manpower requirements defined by ACM-02 were placed in the AIMD. The ACM-02 model was exercised to determine the workload for each billet.[2] Flying hour factors were found by dividing the average flying hours per aircraft per month in wartime by the peacetime flying hours. The wartime flying programs were from the aircraft's mission-specific flying hour objectives. The peacetime flying programs were those experienced during the time frame of ACM-02's B values. These factors vary from 1.4 to 3.6--that is, the wartime flying program was from 40 percent to 360 percent more intense than the peacetime program. These factors were then applied to the ACM-02 billet workloads. The resulting workload

[2]The factors in the most recent ACM-02 publication were used to determine workload by NEC. The wartime availability of 60 hours per week used to convert workload to billets conforms with Navy policy for at-sea manpower availability.

(termed wartime work) was then divided by an availability of 60 hours per week to calculate new billet requirements.

The resulting wartime TAD requirements are shown in Table III-1[3] along with the peacetime ACM-02 billet requirements. Across the carrier air wing, the wartime manpower is 39 billets or 26 percent above the current ACM-02 definition of manpower requirements.

The manpower shortfall is most acute in work centers where the peacetime utilization is high. In the Electrical/Instrument shop, there is high utilization of personnel in peacetime because the work is not specific to NECs (most of the work does not require a particular skill).

Table III-1

ACM-02 TAD MANPOWER FOR WARTIME AVIONIC WORKLOADS: SINGLE CARRIER

Shop	All Squadrons	
	Peacetime	Wartime
COMM/NAV	35	36
ELEC/INST	10	16
Fire Control	18	22
Radar/ECM	28	34
SACE/INS	21	33
VAST	21	24
ASW	5	6
MOD Repair	10	16
	---	---
Total	148	187 (+26%)
Utilization Rate	15-60%	30-90%

[3]The wartime figure for the VAST (Versatile Avionics Shop Test) shop was constrained by facilities to a maximum of 24 billets. The wartime workload would justify 31 TAD billets, thereby indicating a bottleneck or overload in the VAST work center that could only be satisfied by increasing the number of test stations (or transferring VAST work from the carrier either ashore or to other test equipment). This will be examined in more detail in Chap. IV.

When the flying hour factor is applied to the peacetime workloads, 60 percent more personnel are required than are specified by ACM-02. Large wartime shortfalls also appear to exist in the SACE/INS work center.

Work centers where there are relatively small NEC workloads, such as COMM/NAV and ASW, are affected only slightly or not at all by increasing the workload. The wide range of NECs and the relatively small non-NEC specific workloads allow these shops to easily absorb additional work.

Certain aircraft types are affected more severely than others when workload is increased. The F-14, S-3, and A-7 represent 29 of the 39 billet difference between peace and war. These aircraft represent the critical fighter, attack, and antisubmarine capabilities of the carrier. The S-3A, because of the significant increase in flying hours in wartime, has almost a 40 percent shortfall in personnel requirements.

The above exercise highlights a potential problem in the capability of AIMD manpower to respond to wartime demands. The linearity assumption applied in the exercise may represent an overstatement of the effect of flying hours on workload. However, where peacetime utilization is high, such as in the Electrical/Instrument and SACE/INS work centers, any positive effect of flying hours on workload will overburden the manpower resources and degrade aircraft support capability.

Requirements Based on Total Carrier Workload

The wartime requirement in Table III-1 is based on the current concept of squadron TAD manning. There are two types of I-level

billets--those that are permanently assigned to an AIMD and those that come as Temporary Additional Duty from the aircraft squadrons that an AIMD supports. The TAD concept resulted from the desire to move repair personnel to the location where the work is generated. Hence, TAD billets are provided to accomplish component repair, and "permanent party" billets cover maintenance management and test equipment repair. The practice of determining squadron requirements as if the aircraft were operating in an isolated environment, however, results in a overstatement of total billets when looking at the combined aircraft workloads on board a carrier.

Although the wartime workload increases personnel utilization, there are still certain shops and skills where the projected utilization rate is relatively low. As suggested in the DRMS, overall utilization can be increased by determining manpower requirements on the basis of the total workload of the AIMD. Applying the consolidated workload by skill type across all aircraft results in lower personnel requirements for carrier AIMDs. This reduction is due to the "integer" gain from manning based on total workload rather than on pieces of the total work. Under the squadron TAD concept, 20 hours of work per week in each of two squadrons results in a requirement for two billets--one for each squadron. The consolidated workload of 40 hours per week calls for a single billet.

The magnitude of the personnel savings possible with an AIMD manning approach can be approximated by examining the workloads generated from ACM-02. Using the wartime workloads developed above and summing across all aircraft, the total work for each NEC within each

shop can be determined. Dividing the total NEC workload by availability (60 hours per week) yields the number of AIMD billets by NEC. These values are shown, along with the current ACM-02 and the wartime TAD figures, in Table III-2.

The wartime squadron TAD requirement of 187 billets is reduced to 147 billets when manpower is determined on an AIMD basis.[4] Although the total AIMD wartime requirement of 147 nearly equals the ACM-02 figure of 148, the mix of people is not optimal. Excess requirements of

Table III-2

SQUADRON TAD AND AIMD MANPOWER REQUIREMENTS

	ACM-02	TAD Wartime	AIMD Wartime
COMM/NAV	35	36	18
ELEC/INST	10	16	14
Fire Control	18	22	17
Radar/ECM	28	34	28
SACE/INS	21	33	27
VAST	21	24[a]	24[a]
ASW	5	6	4
MOD Repair	19	16	15
Total	148	187	147
Utilization Rate	15-60%	30-90%	90+%

[a] Facilities constraint.

[4]Approximately 15 of the 40 fewer billets are a result of combining the two squadrons of F-14s and A-7s into 24 aircraft squadrons. The combining of squadrons of like aircraft has been analyzed by the Center for Naval Analyses as part of their effort in the CABAL study. The estimated 15 billet savings is based on comparing the wartime TAD requirements of the F-14 and A-7 squadrons with the requirements indicated by dividing total aircraft workload by availability. The resulting number may differ slightly from CNA consolidated squadron results.

29 billets in certain shops offset shortfalls of 28 billets in the remaining avionics work centers. For example, in the COMM/NAV shop, low NEC workloads cause the AIMD manning requirement to be only half the total squadron TAD values. On the other hand, the high peacetime utilization and a large amount of non-NEC specific workloads force the wartime AIMD requirement to be greater than the current ACM-02 level of manning in the Electrical/Instrument shop (although less than a wartime squadron TAD requirement). Overall, shortfalls exist in the following skills: Electrical/Instrument (AEs), SACE/INS (for the AE7116, AE7149, AQ7953 NECs), VAST, and module repair. Thus, even though wartime "AIMD manning" yields approximately the same requirement as the TAD peacetime ACM-02, the mix of NECs is not correct for wartime.

The resulting consolidated manpower billets could be managed in either of two ways. The current practice of squadron TAD management could be maintained. However, since the consolidated requirements would not have enough billets in each skill to assign a billet to each type of aircraft, billets would have to be assigned to aircraft types on a selected basis. For example, if the consolidated requirement resulted in three billets with a specific skill and six squadrons had components requiring that skill, only three of the squadrons would have the skill identified in their squadron manning documents (SQMDs). This practice of selective manning is currently used by ACM-02 in the Module Repair Shop. Although every aircraft has some module repair workload, only certain squadrons ha module repair billets in their SQMDs.

I-Level Personnel Management

A second, potentially more attractive, management philosophy would place all I-level billets under the control of the AIMDs. Component repair billets would still move with the aircraft from sea to shore, but personnel would be TAD from AIMD to AIMD rather than from squadron to AIMD. AIMD manpower management would give the AIMDs better control and visibility over the personnel assets and would allow closer interaction between the I-level and the requirements and training processes. Also, by assigning personnel to I-level billets, a better continuity of the work force would result and the overall quality and productivity of I-level repair personnel could be increased.

The specific form of AIMD management must be determined--whether billets are under the command of the CV AIMD and sent TAD to NAS AIMDs or vice versa. Also, the initial difficulties of establishing lines of communication and personnel assignment priorities would have to be overcome. However, the potential benefits of having all I-level personnel under the control of the AIMDs should outweigh the initial difficulties associated with changing the management philosophy.

TEST EQUIPMENT

A wide range of test equipment is required to repair the diverse mix of avionic components installed on a carrier's many aircraft types. These equipments range in complexity from inexpensive, general-purpose multimeters to expensive, highly specialized automated test sets designed to test a limited number of components. Test equipment, like manpower, is a potential constraint in the intermediate level repair

process. Test equipment availability, utilization, and supportability are important issues in the current repair structure.

Availability

Test equipment capacity is a function of both the number of test sets installed and their availability. Availability, in turn, depends on the failure rate of the equipment and the time required to repair it. Unfortunately, data on test equipment availability could not be identified from standard Navy data sources. Therefore, full wartime availability of seven days per week, 24 hours per day, was assumed except in the case of VAST; informal discussions indicated that an average of about 3.5 out of the 4 VAST stations on the carrier were operational at any one time.

The DRMS suggested that it was difficult to maintain test equipment on the ship because of the range of repair parts and maintenance skills required. The study further hypothesized that availability would be increased if test equipment were moved ashore because the demand for test equipment spare parts and maintenance skills would be centralized in fewer locations, resulting in shorter expected downtimes for broken equipment. In addition, when the centralized test equipment workload warranted multiple test sets, there would be redundancy not found on the carrier, where typically there is only one test set per ship. This hypothesis cannot be tested fully because of the lack of data.

Peacetime repair times (less AWP time) at shore-based and shipboard AIMDs were compared on the assumption that if, under the current repair structure, test equipment availability on board the ship were

significantly worse than that at shore-based facilities, the afloat repair time would be longer. This comparison showed that with the exception of a few components, afloat repair times were generally no longer than those ashore, indicating that in peacetime, for the current repair structure, test equipment availability was no worse on board the carrier. These results are not conclusive, however, because deployed carriers in peacetime tend to get favored treatment in terms of spare parts and special technical assistance that might not be available in wartime.

Wartime Utilization

Based on the operational test equipment availability assumptions discussed above, the wartime utilization rate of each piece of avionics test equipment was computed.[5] As expected, the projected wartime utilization rate for most of the test equipment was very low (less than 20 percent). With the exception of VAST, loading on the most highly used piece of equipment in each avionics shop rarely exceeded 60 percent. This means that, given full operational availability, most shops have sufficient wartime capacity. VAST, on the other hand, showed a wartime utilization rate of 160 percent--the wartime workloads exceed VAST capacity by 60 percent.

Under a sustained wartime scenario with all aircraft flying continuously at programmed rates, the backlog for VAST would continue to grow. The important issue is what impact this growing backlog will have

[5]3M Elapsed Maintenance Time (EMT) was used as a proxy for test equipment time.

on aircraft availability. A number of factors tend to partially alleviate the impact over a limited time horizon. The on board stock of spare parts will be consumed as the backlog grows, so backlog does not directly equate to holes in aircraft (or backorders against supply). To the extent that backorders can be consolidated on the fewest number of aircraft through the cannibalization of components, the impact is further reduced. Finally, priority repair management, which controls the induction of components into the VAST shop based on aircraft needs, will also reduce the impact. Priority repair and its potential value is discussed below in the section on maintenance management.

Figure III-1 shows the effect of the VAST capacity limitation on the S-3A, assuming a full AVCAL and that all aircraft (including the F-14 and the E-2C) are flying at sustained wartime rates. The measure of aircraft availability is fully mission capable for avionics only (FMCA). The number of days represents days of flying at wartime rates. The availability measure is computed assuming full cannibalization to minimize the number of aircraft down (not fully mission capable for avionics). Note in the figure that the VAST limitation does not have a drastic effect for about two weeks, after which the percent FMCA aircraft begins to degrade dramatically compared with the case where there is no VAST constraint. Without cannibalization, the situation is, of course, much worse. Figures III-2 and III-3 show similar data for the E-2C and the F-14A. The effect of the VAST limitation on the E-2C occurs earlier than S-3A whereas the F-14, with larger numbers of aircraft, can be sustained for a longer period.

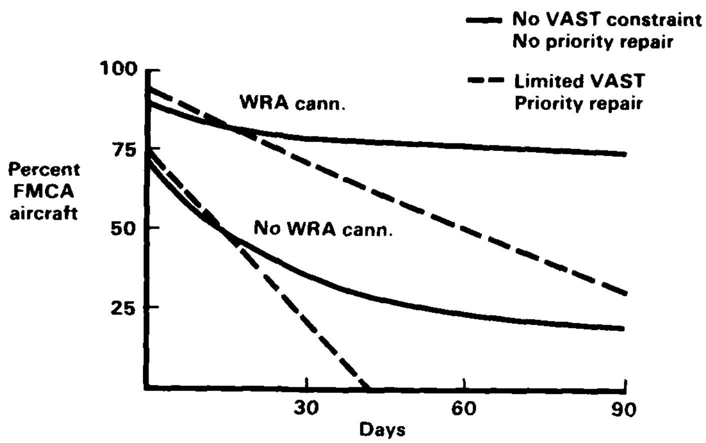


Fig. III-1—Effect of VAST limitations and priority repair: S-3A wartime example

In sum, the present VAST capacity is probably sufficient only for those wartime scenarios where carrier aircraft are required to operate at programmed rates for limited periods of time, followed by periods when the carrier is able to stand down and thus has time to work off the VAST backlog. If, however, the carrier is required to operate its aircraft for longer periods of time where the average flying rate is equal to or exceeds the programmed rates, as the VAST backlog grows aircraft capability will begin to degrade. Priority scheduling of VAST provides only a short-term remedy for the capacity shortfall.

VAST Backlog Analysis

The issue, then, is what alternatives are available to reduce the VAST backlog for longer, sustained scenarios. Three options were

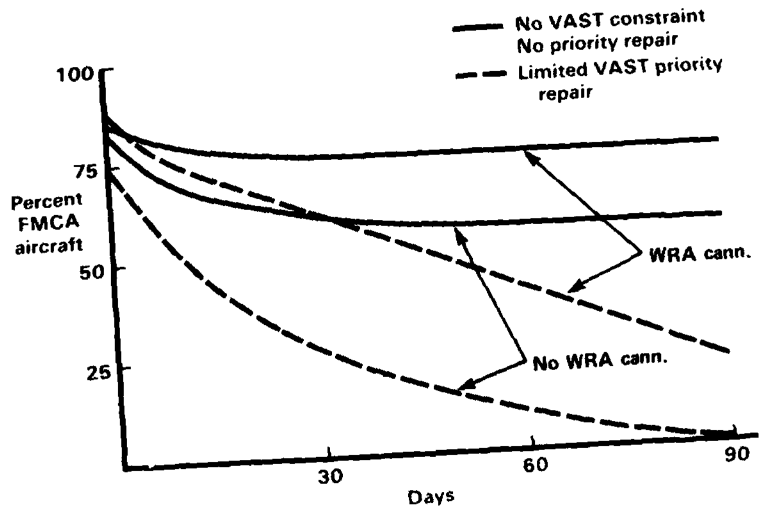


Fig. III-2—Effect of VAST limitations and priority rep.ir: E-2C wartime example

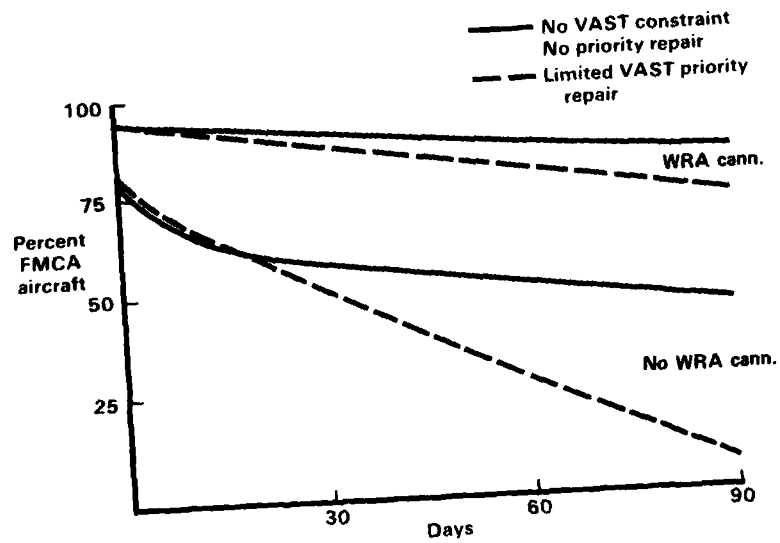


Fig. III-3—Effect of VAST limitations and priority repair: F-14A wartime example

addressed in the CABAL study: reevaluate required wartime flying programs; move some repair off VAST; and buy additional VAST capacity.

The preceding analysis was based on the Navy's programmed wartime flying rates. For the S-3A, however, current Navy policy does not provide spare parts to support that S-3A program because of parts shortage throughout the whole system. The S-3A program used to compute the carrier spare parts requirements is about 68 percent of the official program. If it is assumed that the lower rate is all that can be supported, then the wartime VAST requirement would be reduced from 160 percent of current capacity to 132 percent.

The second alternative is to move some repair off VAST. There are two options: move repair to other test equipment on the carrier which is not fully utilized, or move repair to shore-based AIMDs. VAST currently supports repair of both Weapon Replaceable Assemblies (WRAs) and Shop Replaceable Assemblies (SRAs). Because of the flexibility provided by priority repair (to be discussed in the maintenance management section), it is important to keep as much WRA repair on board as possible. Because the WRAs tend to require more sophisticated test equipment, only SRA repair, for the most part, can be moved to other test equipment. Therefore, only the option to move SRA repair off VAST was considered in the analysis. If all SRA repair were to be moved, either to other shipboard equipment or to shore-based facilities, and the S-3A flew its full program, the VAST capacity requirement would be reduced to 140 percent of current capacity.

It is unclear how much of the current SRA workload can be removed from VAST. A great deal of VAST SRA repair has already been moved to automated SRA testers in the module repair shop; how many more could go

to these testers is not known. The existing testers were built primarily to test digital avionics, not analog equipment, and much of the remaining VAST SRA repair may be of the latter type. Discussions with Navy personnel indicate, however, that an analog tester is being procured, which may solve the compatibility problem. Even if it is technically feasible to move all SRA repair to other shipboard equipment, such a move will incur costs to procure test program sets and interface modules.

Moving VAST SRA repair ashore would also incur costs for additional spare parts to cover the added transportation pipeline. The analysis described in Ref. 8 estimated this cost to be about $1.2 million per carrier for the full S-3A flying program (this investment would cover the additional SRA spares needed for the E-2C, F-14, and the S-3A). With much of the force deployed in wartime, VAST stations at shore-based facilities will have excess capacity so no additional equipment need be procured, and the marginal cost of the incremental transportation requirement should be insignificant.

If the lower S-3A flying program is assumed and all SRA repair is moved off VAST, the capacity requirement would drop from 160 percent to 114 percent and the additional SRA costs would be about $1 million for the shore repair option. The results of the two options are summarized in Table III-3.

The final alternative would be to buy additional VAST capacity. At least two more stations are required to meet the full wartime flying program repair requirement, but given the shortage of space on the carriers and high cost of additional stations, especially when compared with the cost of other alternatives, this does not seem to be a realistic option.

Table III-3

VAST CAPACITY REQUIREMENT
(SRA Wartime Program)

Items Tested	Programmed	Current Stockage Computations
WRAs + SRAs	160%	132%
WRAs Only	140%	114%

MAINTENANCE MANAGEMENT

Two potentially important aspects of AIMD/supply management were not considered in the DRMS: priority repair and AWP management through SRA cannibalization of WRAs. AWP management is primarily a supply problem and will be discussed in the next chapter. Priority repair, although requiring good visibility of supply status, is primarily an AIMD job control function and is discussed here.

Because the AIMD is the primary source of supply for avionics reparables, a close working relationship between maintenance and supply management is required. Existing policies that attempt to monitor the stock status of pool items and aircraft status so that critical items can be inducted for expedited repair demonstrate that the importance of priority repair is widely recognized within the Navy, although the success of its implementation seems to vary across carriers. This concept is important because it can dramatically shorten repair times for those critical items that are keeping aircraft down. The value of

priority repair could be further strengthened by providing maintenance management with:

- o Supply data, particularly stock status and demand rate.
- o Tools to use this information in routine induction scheduling decisions.

The potential value of priority repair was clearly demonstrated by the special analysis of VAST, briefly discussed above. Once the potential constraints on performance defined by VAST capacity limitations were identified, allocation was formulated as a queuing problem. The analysis used a scheduling rule that gives first priority to items with the most outstanding backorders (holes in aircraft) and then, if capacity remains, sequentially inducts those with the lowest number of days of demand of stock on hand.[6] This rule is slightly more sophisticated than the one typically used by the Navy, which schedules any backorder as an expedited repair (EXREP), and it would require more visibility over supply data and information system support to implement effectively.

The queuing analysis was run assuming a continuous 90-day scenario in which all aircraft with VAST reparable items (E-2C, S-3A, F-14) flew at their full programmed rates. As noted in the previous section, this schedule generates repair requirements equal to 160 percent of VAST capacity. Nonetheless, even though the backlog outstanding at the end

[6]The number of days of stock on hand is simply the serviceable stock level divided by the expected daily demand rate (DDR). DDR is the product of expected removals per flying hour and programmed flying hours per day.

of the 90-day scenario was equivalent to 51 days of capacity, the maximum number of expected backorders for any one component was only two. This includes those expected to be awaiting parts based on the analysis of indentured components discussed in the following chapter.

This result was achieved only by concentrating available repair capacity on an increasingly small subset of components--those critical components for which there were backorders causing holes in aircraft. As is shown in Fig. III-4, only 5 percent of the 444 reparables assigned to VAST were being scheduled after day 60, and 20 percent were not tested at all during the 90-day scenario.

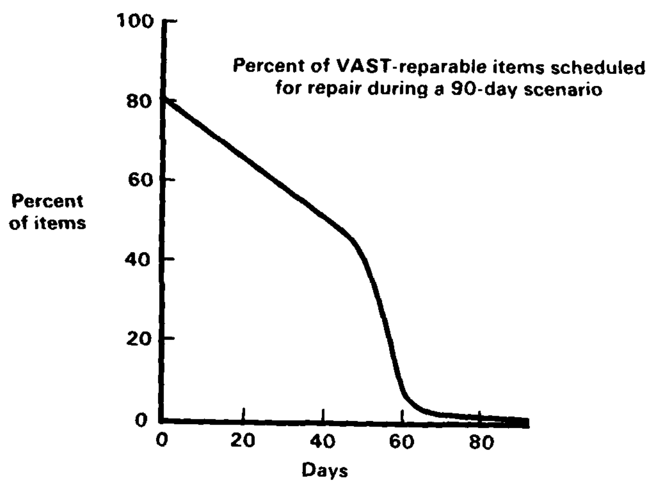


Fig. III-4—Priority repair scheduling

Unfortunately, the effects of this backlog on projected operational performance are less encouraging. Even with the assumptions of cannibalization, under which holes created by stock shortages are concentrated on the smallest possible number of aircraft, more aircraft may be down than is implied by the maximum number of outstanding backorders.

Figures III-1 through III-3 contrasted the impact of spares shortages on the operational availability of the E-2C, S-3A, and F-14A on the assumption that there is no VAST capacity limitation with those based on the queuing analysis described above. Figures III-5 and III-6 compare these results (for the full cannibalization case) with those that would be expected if there were no priority repair for the S-3A and the F-14A.

Priority scheduling of VAST does improve performance somewhat during the early days of the scenario, but as the backlog and repair times grow, performance is increasingly affected. Bear in mind that for this analysis only VAST is operating with priority repair and other components are being repaired at the rates measured in peacetime. With no priority repair, aircraft availability falls off much more drastically than shown with priority repair. The message is that: (1) wartime performance can be expected to deteriorate markedly from that based on projection of peacetime maintenance performance; (2) priority repair can limit the rate of performance degradation; but (3) if any fully mission capable sorties are to be flown late in a 90-day scenario, organizational level maintenance must cannibalize to the fullest extent to minimize the number of down aircraft.

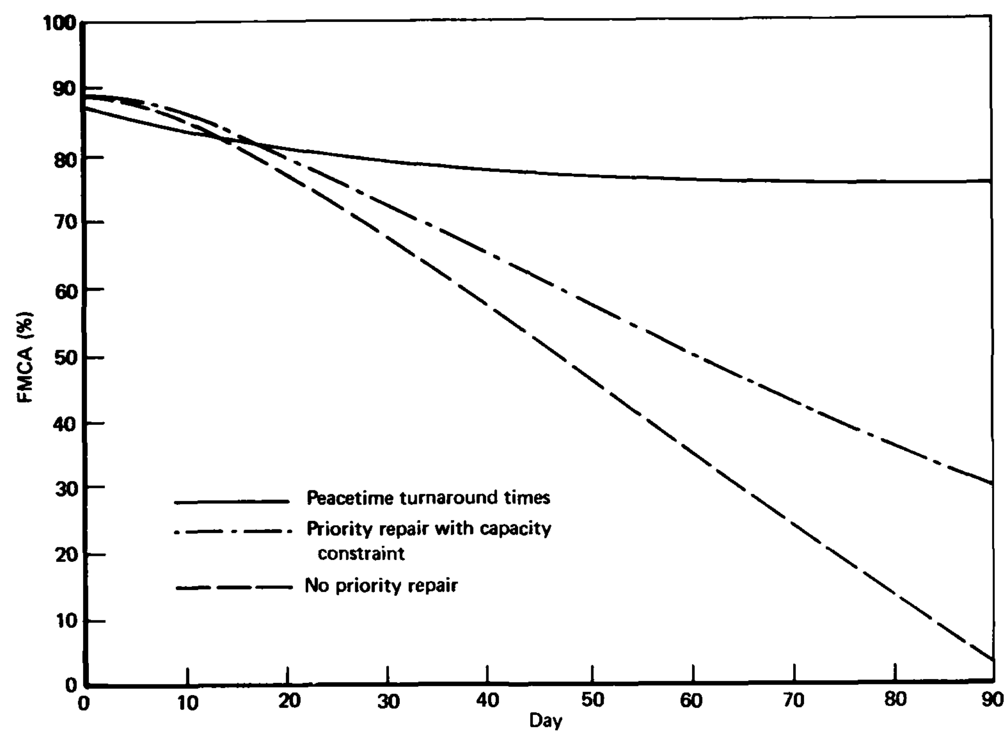


Fig. III-5—Effect of VAST limitations and priority repair:
S-3A with full cannibalization

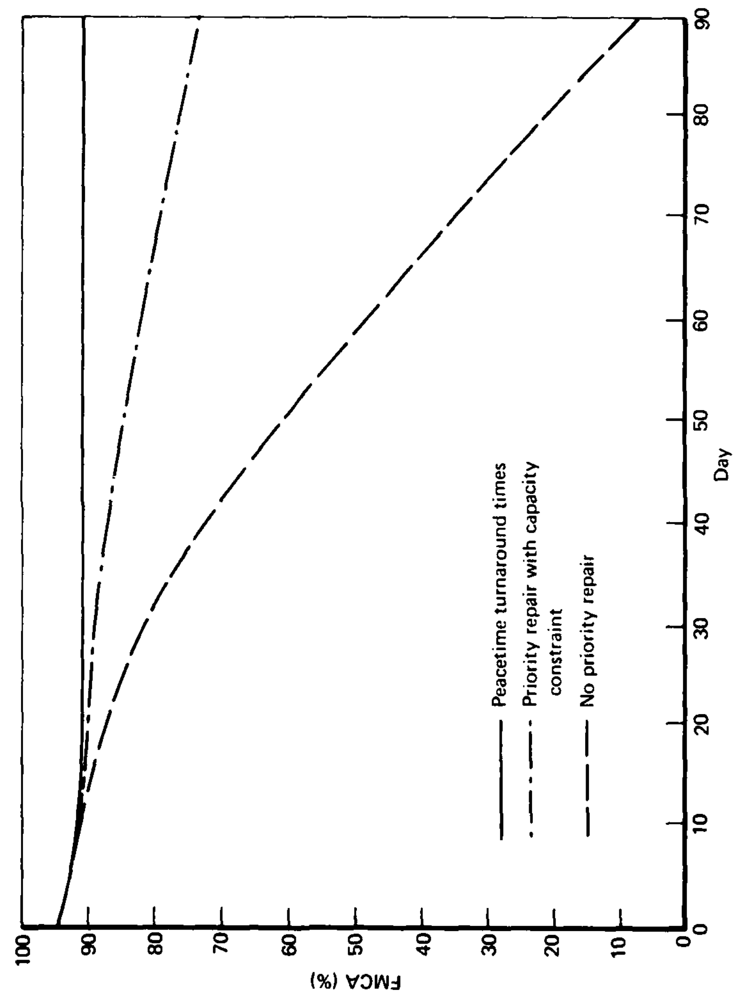


Fig. III-6 — Effect of VAST limitations and priority repair: F-14A with full cannibalization

While test equipment capacity does not appear to be a problem in work centers other than the VAST shop, the analysis has assumed that the levels of spares, manpower, and test equipment developed through the requirements process are available. In the real world, spot shortages of resources will exist. The results of the analysis performed for VAST can be generalized; priority repair can be used to compensate for other short-term resource shortages, particularly manpower or spare parts, if maintenance management uses information on supply stock position and aircraft availability as the basis for its scheduling decisions.

Figure III-7 shows the difference between expected FMCA with and without cannibalization for the E-2C; both curves are based on the VAST queuing analysis described above. The E-2C experiences more severe degradation in full-cannibalization availability than the other aircraft because of the small pool of aircraft available for cannibalization.

The small scale of squadrons such as the E-2C provided part of the motivation for the DRMS alternative [Ref. 10]. Cannibalization does permit continued operation of the E-2C by day 90 although the aircraft's flying program can no longer be met. Reducing the VAST capacity shortfall, which is an important cause of performance degradation, could improve E-2C performance considerably.

The effects of some of the options for reducing the VAST capacity shortfall discussed in the previous sections are shown in Figs. III-8 through III-10. They contrast expected FMCA given the current capacity constraint with that expected if: (1) all SRA repair was removed from VAST or (2) two additional VAST stands were installed on the carrier. All three figures assume full cannibalization of WRAs and that the S-3A is flying at its full programmed rate.

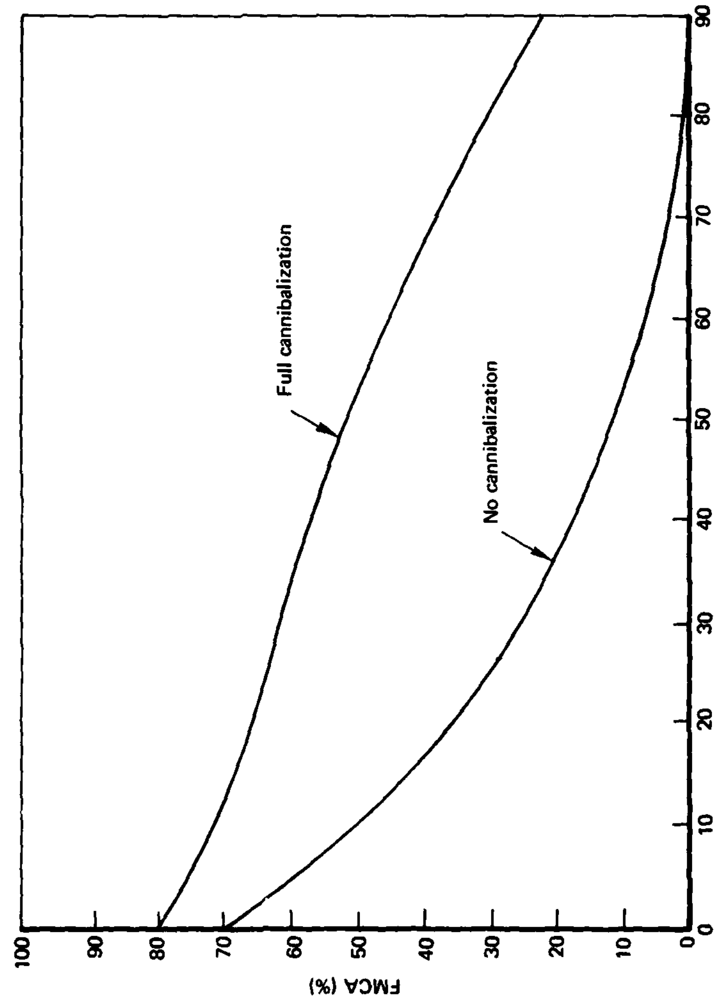


Fig. III-7—Contribution of cannibalization to performance:
E-2C with priority repair

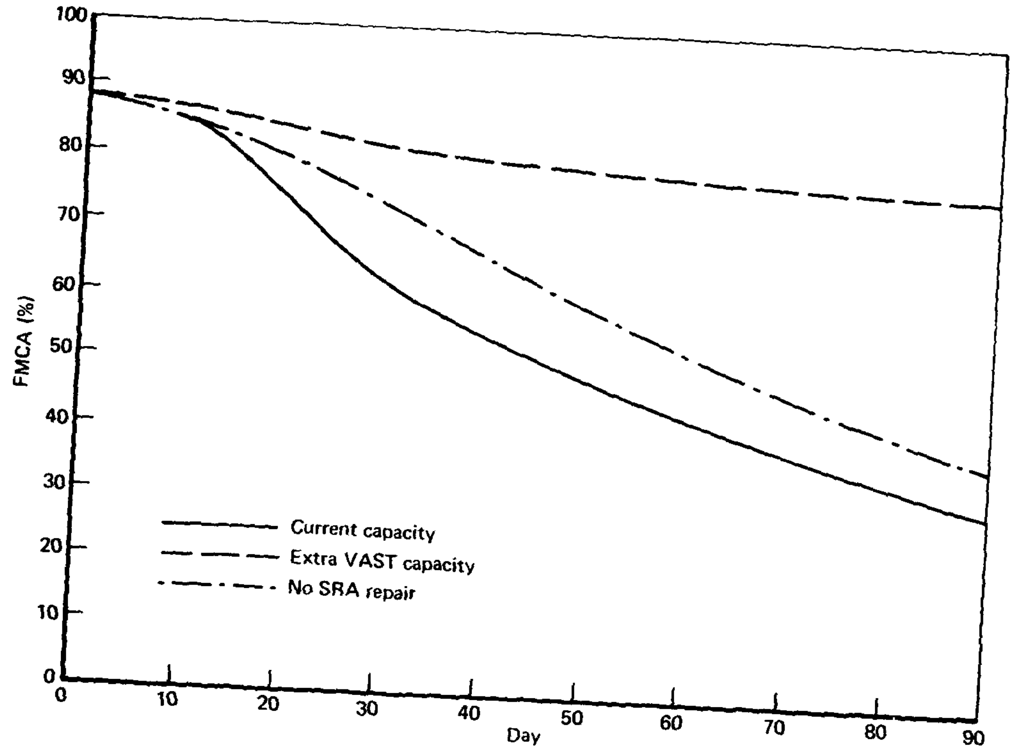


Fig. III-8 —Performance effects of reducing the VAST capacity shortfall:
S-3A with full cannibalization

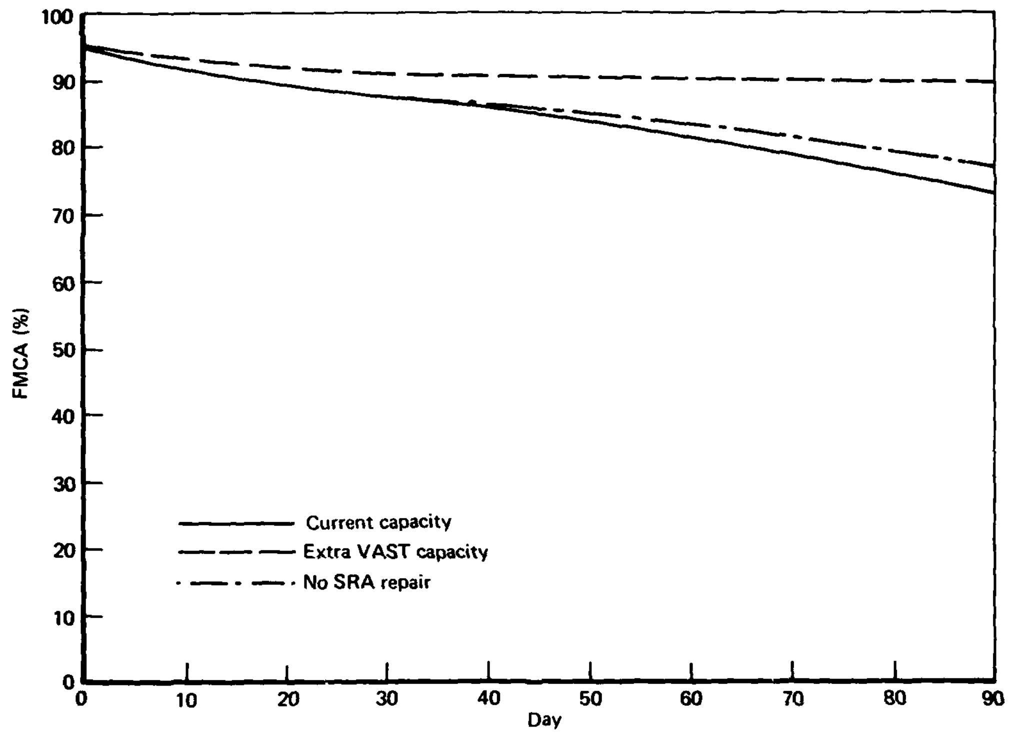


Fig. III-9—Performance effects of reducing the VAST capacity shortfall: F-14A with full cannibalization

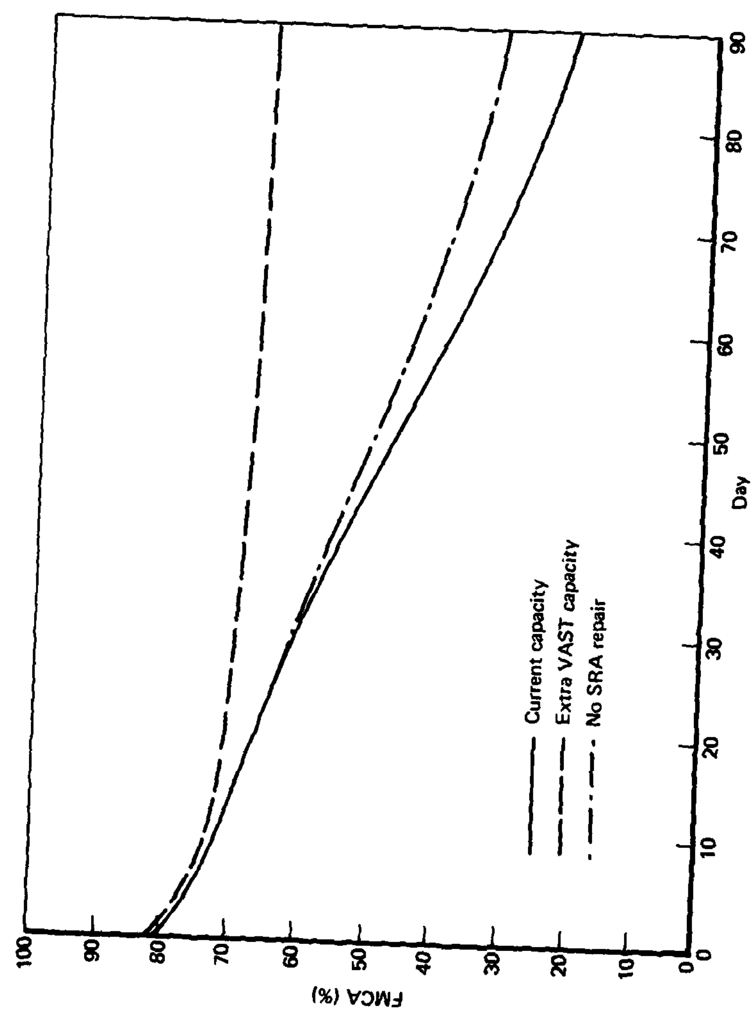


Fig. III-10—Performance effects of reducing the VAST capacity shortfall; E-2C with full cannibalization

Relaxing the VAST capacity constraint has a significant effect on performance, particularly with priority repair. Availability (FMCA) with a reduced capacity shortfall and priority repair is uniformly better than that predicted based on extrapolation of peacetime maintenance performance (Figs. III-5 and III-6).

The performance improvement from increasing available VAST capacity could also be realized by decreasing test time demand. Reducing the S-3A flying program and moving SRA repair from the VAST as discussed in the previous section would lower capacity demand to the range where priority repair can compensate (over a 90-day scenario) for the remaining shortfall. Alternatively, if the full S-3A flying program were to be maintained, 337 components would have to be taken off the shipboard VAST station; the cost of filling a 90-day pipeline to repair these components ashore would be about $3 million per carrier. The algorithm used to identify these components selected those with the lowest marginal value of test time--those for which the costs of freeing an hour of VAST capacity were the lowest. The algorithm is described in the CABAL Maintenance Analysis [Ref. 7].

These results of the maintenance analysis interact with those obtained in the supply analysis described in the following chapter. A summary of the maintenance findings and an associated set of recommendations are given in Chap. V.

IV. SUPPLY ANALYSIS

The combined effects of the supply, transportation, and maintenance functions determine the performance of the aircraft material readiness support system. Deficiencies in logistics system performance ultimately appear as supply shortages, but these shortages may be attributable to performance shortfalls in any (or all) of the functional areas.

This chapter discusses the effects of supply policy and transportation on aircraft material readiness (FMCA). In addition to evaluating the implications of current policies and performance, it describes policy alternatives that could improve the performance of the current logistics structure.

ASSUMPTIONS AND DATA EMPLOYED IN THE ANALYSIS

The supply analysis made a number of assumptions concerning the availability of resources for shipboard component repair and for depot level component repair. Average historical repair times were used to represent the average repair times, even in a wartime environment. Previous chapters of the report have shown this not to be true in the VAST shop due to potential wartime overloading of the VAST equipment. The degraded availability of the S-3A, E-2C, and F-14A in wartime because of VAST constraints is not reflected in this part of the CABAL analysis. Thus, the results shown here illustrate the effect of policies *after the VAST overloading problem is taken care of* with one or more of the options discussed.

All spare parts requirements were assumed fulfilled. Thus, the AVCAL does not reflect shortages and resulting O&ST periods due to insufficient wholesale spares procurement. Shortages resulting from funding or other constraints on procurement clearly degrade system performance but are transient and difficult to characterize for policy generalizations. This analysis assumes that funding for spare parts requirements is available and that shortages result only from random variations of failures about historical averages or from error in estimation of repair times, transportation times, wartime AWP, and wartime O&ST.

Cannibalization was assumed to be either complete or nonexistent. In the first case, all backorders are consolidated on the smallest number of aircraft (or WRAs in the case of SRA cannibalization). This tends to overstate aircraft availability and capability compared with peacetime experience and less than fully stressed wartime scenarios since only those components deemed mission essential are cannibalized and not all available aircraft are required in those cases. The flight line will probably not exercise the full cannibalization option except in very high sortie rate scenarios with stringent mission requirements.

Finally, it should be kept in mind that this study deals only with avionics components and therefore the effects of other aircraft components (such as engines) are not shown.

All of these assumptions cause the supply analysis to overstate aircraft availability, especially compared with peacetime availability, which is affected by resource shortages and does not have a requirement for complete cannibalization and full mission capability. Comparison of

peacetime aircraft availabilities with those currently experienced showed the model predictions to be high for the F-14A (which suffers from problems with engine and non-avionic components), high for the S-3A (for which there are significant stock shortages resulting from past failure to procure adequate assets), and fairly close for the E-2C. The results of the supply analysis discussed in this chapter must be viewed as the effect that policy and resource changes would have on aircraft not dominated by other resource shortages.

The Dyna-METRIC model was tested on its prediction of AWP and component shortages in a peacetime flying program. This tested not only the model's representation of component repair but also the data base of historical removals and the approximation of current AVCAL supply policy. Table IV-1 illustrates the comparison of model-predicted AWP for the F-14A and the historically measured AWP for the same set of components. Note that the total quantity of components in AWP condition, the grand average (average of averages) AWP per component, and the maximum average AWP across components all fall close to the predicted values for the set of F-14A components considered in the study.

Table IV-1

COMPARISON OF MODEL PREDICTION OF PEACETIME AWP TIME
WITH HISTORICAL VALUES
(F-14A)

	Total Number of Avionics WRAs AWP	Component Grand Average	Maximum Average AWP
Dyna-METRIC Prediction	19.7	.08	1.1
Peacetime Experience	18.4	.08	.9

This closeness of peacetime prediction was found for the other aircraft types as well and assures that the model and data representation for that part of the logistics system under review are accurate.

An important aspect of the analysis was that supply requirements were based on data elements differing from those used in performance evaluation. Supply requirements were created (as they are by the Navy) using constrained repair times and constrained peacetime AWP times. The constraints prevent statistical anomalies from driving the supply requirements too high and the peacetime AWP times are the only data available for estimating AWP. Performance evaluation runs used unconstrained repair time data to affect the time to repair so that the supply requirements were in "error." This, of course, also happens on actual cruises, creating a discrepancy between the predicted and actual values and leading to shortages of certain components. The Dyna-METRIC model produces its own prediction of wartime AWP times, which can differ significantly from the peacetime experience. This also causes a prediction error and potential component shortfalls. Finally, while the supply requirements were based on certain historical averages, the Dyna-METRIC model considered random occurrences about the averages and therefore predicted the effects of deviations from average values. Thus, an important aspect of the supply analysis was that predictions of supply requirements could differ significantly from the needs of a simulated cruise for some of the same reasons experienced on actual cruises.

CURRENT STRUCTURE AWP TIME AND IMPLICATIONS FOR REPAIR ASHORE

AWP and the Motivation for Increasing the Scale of Repair

WRAs frequently await parts for repair because of shortages of consumable components and shortages of reparable SRAs compared with the number of such subcomponents on order for resupply or in shipboard repair. A snapshot of the WRAs in local repair aboard ship currently would show about 50 percent awaiting parts and 50 percent in some stage of repair or awaiting repair. On the average, in peacetime, about 25 percent of the WRAs requiring repair must await parts and those that do average about 25 days in the AWP state. Furthermore, those components which become AWP require about 50 percent additional elapsed maintenance time and man-hours to repair. The current system clearly pays a high price for AWP in terms of available WRAs, turnaround time, and maintenance man-hours (not to mention the AVCAL cost for additional WRAs to cover the incidence of AWP--about $11 million per carrier for the avionics components in the study). Wartime AWP quantities and times are likely to considerably exceed the peacetime experience since the AVCAL, provided to support wartime flying rates, permits significant AWP rates to occur at peacetime flying rates.

The DRMS observed these costs and hypothesized that a larger scale AIMD, such as one ashore supporting several carriers, would be more likely to generate the demands needed to warrant stocking a more complete rate of repair parts, which would reduce WRA AWP times. Furthermore, the larger scale would provide more opportunities for SRA cannibalization (consolidating the repair parts shortages when several similar WRAs are AWP for different subcomponents).

Current Structure Performance and Reduction of AWP

The discussion of the CABAL supply analysis begins with an evaluation of the effects of AWP on aircraft availability at wartime flying rates. The effect of AVCAL stockage additions not considered at the time of the DRMS is addressed next. Finally, the role of SRA and WRA cannibalization in mitigating the effect of AWP on aircraft availability is examined.

Wartime AWP was projected by Dyna-METRIC by using the scenario to drive SRA and repair part removals, comparing replacement requirements with supply quantities, projecting shortages, and cannibalizing where possible to limit the effects of these shortages. Subcomponent shortages were then "rolled up" to higher-indentured components through use of configuration data. This procedure was used to relate subcomponent shortages to the number of WRAs AWP. One option in the model was to disable this processing of subcomponents and show projected aircraft availability when no AWP was present. Table IV-2 shows the effect for the E-2C, S-3A, and F-14A. Note that the AWP effect, although significant, is moderated somewhat by WRA cannibalization. Clearly, AWP is not the only aspect of component repair and supply which is dominating performance. The later section on supply policy alternatives will illustrate the potential for further improving aircraft availability by using an availability measure as the objective function in requirements computation.

Table IV-2

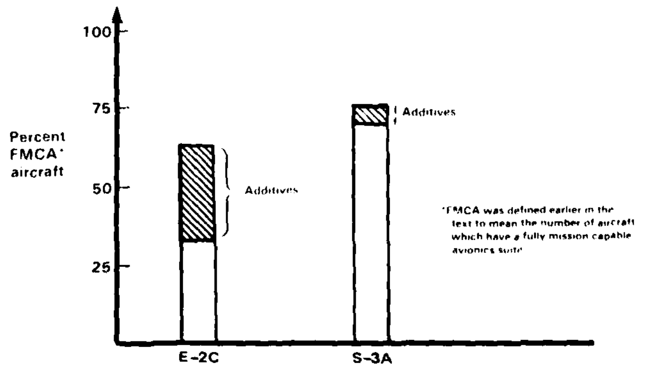
EFFECT OF AWP ON AIRCRAFT AVIONICS AVAILABILITY
(Percent FMCA)--Day 90 of Scenario

	F-14A		S-3A		E-2C	
	WRA Cann.	No WRA Cann.	WRA Cann.	No WRA Cann.	WRA Cann.	No WRA Cann.
Without AWP	92	64	77	37	67	36
With AWP	89	52	74	24	64	38

Currently, a number of stock additives are provided to the AVCAL to increase the range of stock and reduce AWP. These additives, not considered in the DRMS, increase the cost of the AVCAL and reduce the AWP in the air logistics structure. They include:

- Front Loading. Additional consumable components are procured to increase AVCAL range even though they would not be stocked according to demand-based criteria.
- SAVAST. Additional components cover attrition items based on previous cruise demands, derived from the Ships AVCAL Asset Demand Tape (SAVAST). This update to the AVCAL also helps protect the deploying carrier from the considerable inaccuracies of configuration and consumable item removal history within the basic AVCAL data.
- Small Squadron Addition. Additional items are purchased for squadrons with four aircraft or less to prevent zero stockage under AVCAL range rules when removal rates are low.

AVCALs created with and without these additives were input to Dyna-METRIC and compared under the wartime steady-state scenario. Figure IV-1 illustrates the cost and effect of these additives on aircraft availability in the current structure. The effect is most dramatic on the E-2C, which gets a small squadron additive (an increase in the number of unique parts carried that is not based on projected demand). Also, the relative cost of these additives for the small squadron is quite high for the E-2C. It will be shown later that the additives provide considerable protection against uncertainty in demand prediction resulting from the poor data on removal history for consumable items. Despite the resemblance to a "patch" on the supply



	E-2C	S-3A
Cost (millions)		
No additives	3 2	19 8
Additives	6 7	20 2

Fig. IV-1—Costs and effects of AVCAL additives on aircraft availability—day 90 of scenario

policy, the additives appear to be a cost-effective technique for reducing AWP.

The previous chapter mentioned the effect of SRA cannibalization on aircraft availability. Figure IV-2 shows this effect in combination with the AVCAL additives. The combined improvement in aircraft availability is significant (about 40 percent for the E-2C and 17 percent for the S-3A) and for the S-3A represents about the same amount of availability improvement projected for the shore-based repair option in the DRMS. It should be noted, however, that effective SRA cannibalization and AWP reduction require a cooperative maintenance-supply interface. It probably requires enhanced data collection and management to maintain high visibility of current AWP conditions, the potential for cannibalization, and the value of reducing certain WRA shortages in terms of aircraft availability.

The potential to reduce AWP through the DRMS shore repair option was examined by identifying the subset of WRAs which had projected wartime AWP times so long that it was worthwhile to incur the transportation times and move WRAs ashore. Under the current 90-day average roundtrip transportation times and under the optimistic assumption that AWP times ashore would be near zero very few WRAs showed improved average processing time if moved ashore.

The analysis was repeated for a 50-day roundtrip transportation time; still only a few components benefited from the shore repair option. The conclusion is that under current transportation limitations and considering only AWP without increasing the cost of <u>carrier</u> stockage, very few items would migrate to shore repair and improve

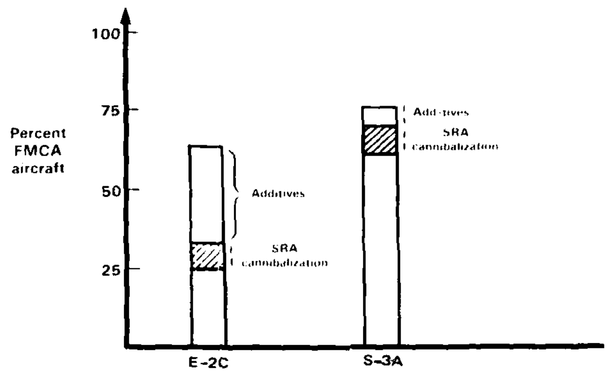


Fig. IV-2—Effects of AVCAL additives and SRA cannibalization on aircraft availability—day 90 of scenario

aircraft availability. Had there been manpower savings by moving repair ashore it would have been possible to obtain additional stock to cover the increased pipelines and maintain an overall constant cost for a given level of performance.

Figure IV-3 shows relative aircraft availability[1] when WRAs are cannibalized completely to reduce all shortages to the fewest number of

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[1]Relative aircraft availability in terms of percentage of aircraft which are FMCA (or FMC) can be misleading with respect to the potential for improvements in availability. A 75 percent availability for the E-2C means that one aircraft is not available while a 75 percent availability for the F-14A means that six aircraft are not available. Since demand-based stockage policies usually do not provide enough low demand components to prevent holes in the last aircraft (cannibalization does not help the last aircraft), it is much harder and more costly to obtain availability improvements for the E-2C than the F-14A from the 75 percent availability rate. A stockage policy which treats all aircraft components equally across TMS is likely to lead to significantly differing availability rates for different squadron sizes. This type of

airframes and when there is no cannibalization. In all cases SRA cannibalization and AVCAL additives are included. The large difference between the cannibalization extremes reinforces the results reported in Chap. III--a high degree of WRA cannibalization is required to maintain reasonably good aircraft availability. But this comes at a cost in manpower, reduced flexibility, and increased breakage as more components are removed and handled. The following section examines some supply policy options to improve aircraft availability and reduce the cannibalization requirements.

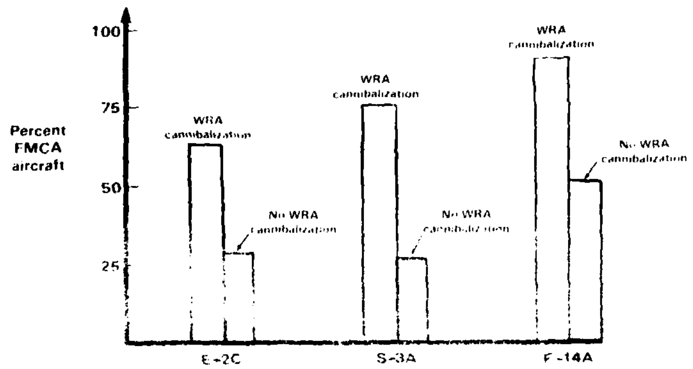

Fig. IV.2--Effect of WRA cannibalization on aircraft availability

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policy leads to the different availability rates shown in Fig. IV-2 even though there has been some favoring of the E-2C with the small squadron additive.

ALTERNATIVE SUPPLY POLICIES

An important task of the CABAL analysis was to determine the value of certain improvements to the current logistics structure as an alternative to the shore-based repair concept. The Navy recognizes that there are shortcomings in the current AVCAL policy and certain extensions have been proposed. For example, in conforming to the DoD RIMSTOP directive [Ref. 12] for secondary item spares, the Navy is developing improved coverage of its resupply pipelines.

It is also apparent that aircraft availability should be considered directly in supply policy. The AVCAL and its planned extensions are based on stockage objectives such as fill rate (percent of the time a requisition can be filled directly from on board spares) and backorders (number of unfilled requisitions). There are methods that, with very little additional data, can determine supply requirements based on desired aircraft availability. This section will illustrate the effect of improved stockage policies with and without the aircraft availability objective and compare performance with the current AVCAL.

One way to view stockage policy is to observe the pieces of the repair and resupply pipeline that are protected by spares and the level at which they are protected. Figure IV-4 illustrates the current AVCAL. Spares are provided in two categories. One category is "pool" or "rotatable pool" spares and provides replacement stock for these components in repair or awaiting repair in the shipboard [illegible]. The pool requirements are calculated on a component by component basis [illegible]

percent fill rate criterion. That is, each component type is provided enough spares to assure that 90 percent of the time a demand for a replacement component can be fulfilled from shelf stock. The protection, or safety level, is then considered to be 90 percent for each item. The second category of spares is provided for the attrition of components (BCM) which cannot be repaired locally either because the level of repair required is not available or because the items are not reparable anywhere (i.e., consumable items). This stock is calculated for reparable components based on a 90-day average BCM or attrition quantity and is sometimes designated "self-sufficiency" or "endurance period" stock since it represents the average number of orders that would be placed in a 90-day period. Both pieces of the AVCAL are calculated based on a projection of wartime removals.

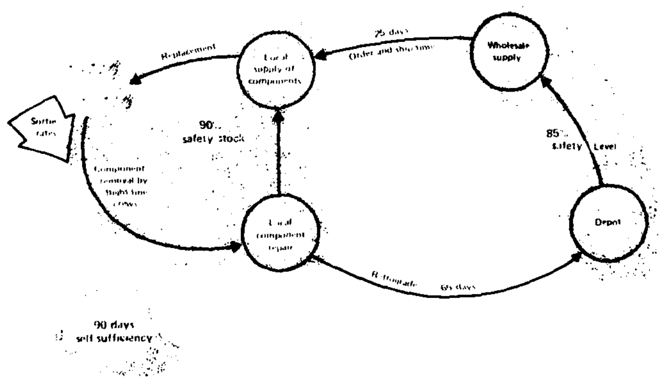

Fig. IV-4—Current AVCAL

Within the wholesale system, spare parts are provided with an average 85 percent fill rate for the average depot repair time. These spares, when available, allow immediate replenishment of orders from the AIMDs. When shortages exist in this wholesale loop, a delay is incurred in satisfying BCM or attrition orders. The wholesale spares are not part of the AVCAL but have been included in this discussion because the performance at the ship is intimately tied to the order-filling performance of the wholesale system.

An immediate observation of the system supply policy (AVCAL plus wholesale supply policy) is that there is no explicit coverage of retrograde and order and ship pipelines. Figure IV-5 shows the effective coverage of the AVCAL. After some period of time most of the self-sufficiency spares will migrate into the retrograde and order and

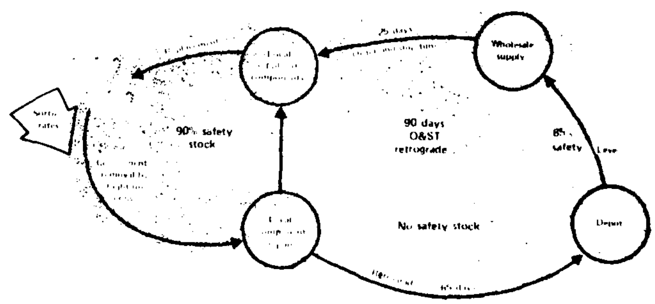

Fig. IV-5—Current AVCAL coverage

ship pipelines. Even with continuing replacement, after about 90 days of flying at peacetime rates half of the spares will have moved into these pipelines. After 90 days of flying at wartime rates, all of the self-sufficiency spares are likely to be in the transportation pipeline, even with continuous resupply. The carrier therefore has 90 days of self-sufficiency only when it initially deploys. Even then, since the attrition and BCM spares are provided without a safety level, any deviation upward from the mean removal rate can cause shortages before day 90. A second observation concerning AVCAL development is that the two categories of spares are treated separately in determining requirements even though the ultimate aim is a total stock requirement. This leads to cases in which neither category shows enough historical demand to warrant stocking under current AVCAL rules--even though the sum of the pipeline quantities exceeds the stockage criterion. The AVCAL processing provides zero spares in such cases, with an overall reduction in protection level.

Figure IV-6 illustrates complete, explicit coverage of the transportation and local repair pipelines. All spares for these pipelines are prepositioned on the ship (in a modified AVCAL) and safety stock is provided for the combined requirement. This coverage is similar to the planned extension of the AVCAL in response to the RIMSTOP directive (although the prepositioning of more than 30 days of war

reserve retrograde spares is at odds with that directive). Given current transportation times and the likelihood of lengthy resupply interruptions, only the prepositioning of the entire retrograde portion was considered. (The reason for not prepositioning is the small cost reduction in safety stock when spares are located centrally for several carriers.)

The pipeline coverage illustrated in Fig. IV-6 was produced in two ways. The first, consistent with planned extensions to the AVCAL, was to determine a requirement for each component type using an 85 percent fill rate objective. The second method was to optimize or maximize an aircraft availability objective through tradeoffs between component

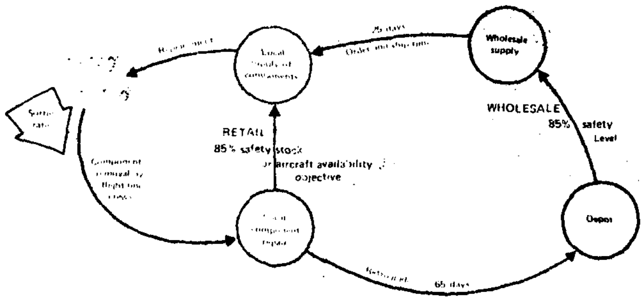

Fig. IV-6—Complete pipeline coverage

supply levels. The optimization process was kept simple to avoid potential implementation problems. For example, the only data beyond that needed in the current AVCAL process are identification of WRAs (that is, a separation of components into WRAs and others) and identification of which components are associated with which aircraft type. It does not require indenture configurations which tie SRAs to WRAs.[2] The optimization can be performed by setting an AVCAL budget target and maximizing the confidence (probability) of not exceeding a target NMC rate or by setting a target NMC rate and confidence level and minimizing the cost of achieving it. The technique used in this study was to set the budget target to the current AVCAL value (or to the extended AVCAL cost from improved pipeline coverage) and to maximize expected FMCA.

Figure IV-7 is a comparison of the optimized AVCAL with the current AVCAL (including additives) for aircraft availability at day 90 in the steady-state wartime scenario. Note that the improvement is most significant in the availability prior to WRA cannibalization. This implies that proportionally less cannibalization is required under the optimized AVCAL. Figure IV-8 shows the effect of increasing the overall spares coverage by covering all pipelines with an 85 percent fill rate criterion, which improves the no-cannibalization availability measure and somewhat improves the full-cannibalization availability measure. Note that for the S-3A a 33 percent increase in expenditure for spares

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[2]If such data were available it would be beneficial to the process. However, the problem of identifying specific component configurations and maintaining up-to-date files for each carrier deployment appears difficult for the current supply system and therefore the optimization process deals only with WRAs.

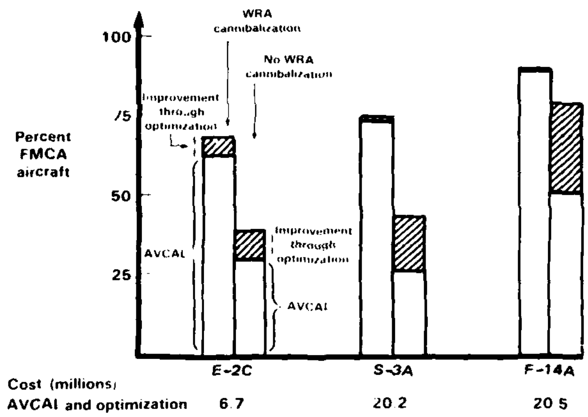


Fig. IV-7—Comparison of the current AVCAL with optimization at the AVCAL cost—day 90 of scenario

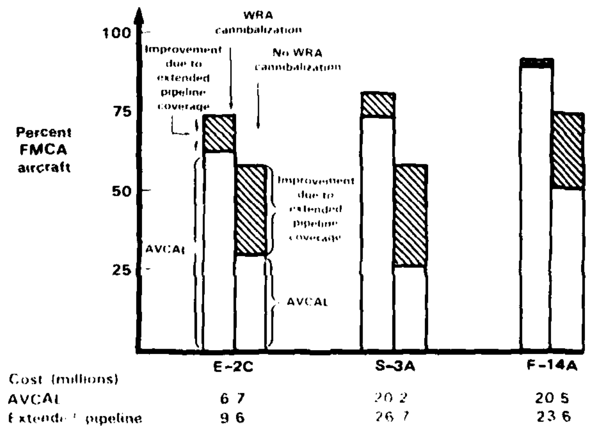
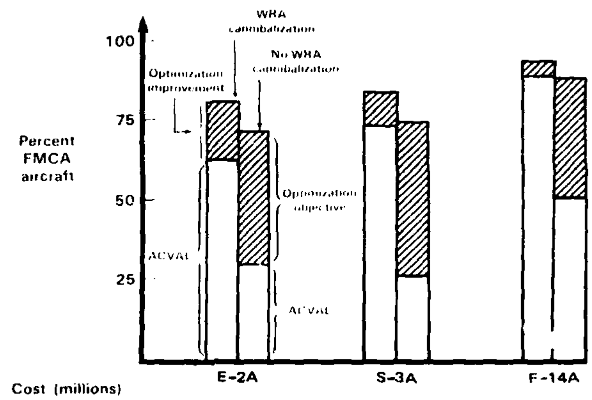


Fig. IV-8—Comparison of the current AVCAL and increased pipeline coverage—day 90 of the scenario

causes about a 7 percent increase in full-cannibalization availability and a 60 percent increase in no-cannibalization availability.

An important finding in the examination of the extended pipeline coverage and the fill rate objective was that it was necessary to provide the current AVCAL additives as well as the extended pipeline coverage. Apparently the additives provide protection from stockout for those components with incorrectly predicted demands or repair times. In other words, the fill rates used in computing stockage requirements might vary considerably from those projected with the actual removal, repair, and AWP rates. Without the additives, the extended pipeline calculation and fill rate objective did worse in some cases than the current AVCAL despite the higher expenditure.

Figure IV-9 illustrates the improvement possible with an aircraft availability objective and the higher expenditure used for the extended AVCAL with a fill rate objective. Note that the requirement for cannibalization is reduced so much that the performance without cannibalization is almost equivalent to the full-cannibalization performance. Furthermore, under full cannibalization, aircraft availability for the avionics suite [illegible] percent for each of the three aircraft types



Cost (millions)	E-2A	S-3A	F-14A
AVCAL	6.7	20.2	20.5
Extended pipeline and optimization	9.6	26.7	23.6

Fig. IV-9—Improvement possible with an aircraft availability objective and increased pipeline costs—day 90 of the scenario

TRANSPORTATION IN THE CURRENT STRUCTURE

Figure IV-10 illustrates a deployed carrier's dependence on transportation. Components which are not carrier reparable (BCM) must be shipped back to CONUS via retrograde transportation and orders for replacement components must be shipped via outbound (order and ship) transportation. When these transportation links are broken, the carrier air wing must operate out of its AVCAL spares which, as was shown in the previous chapter, do not provide adequate protection for these pipelines. This section will further illustrate the dependence of carrier aircraft availability on transportation.

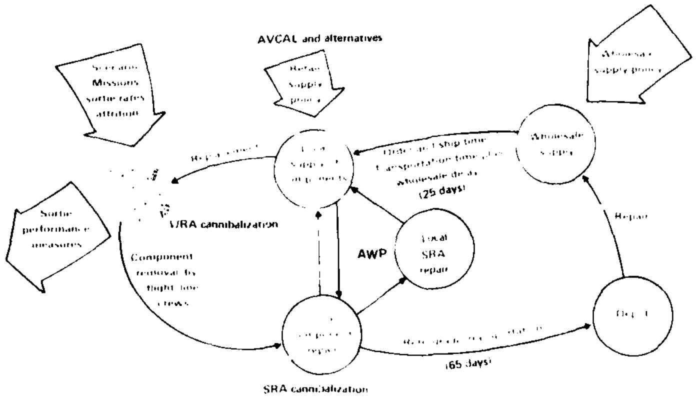


Fig. IV-10—Current average transportation times and the pipelines they affect

The typical method of shipping small components to a deployed carrier is by air parcel post to the operating theater and by carrier on board delivery (COD) aircraft to the ship within the theater. Larger components are typically moved to the theater by the Military Airlift Command system and then delivered by COD. The alternatives to these modes include other forms of mail and surface ship or helicopter delivery within the theater.

Outbound transportation time is measured from the time a part is ready for shipment at the issuing stock point until it is recorded as received aboard the deployed carrier. Retrograde transportation time is measured from the time a component is declared BCM until it is received at a Naval Air Rework Facility (NARF).

Transportation priorities depend on the type of cargo, the urgency of need, and the unit's Force Activity Designator (FAD). The priority of retrograde cargo is generally determined by the type of materiel to be shipped; the priority of O&ST cargo is determined by the urgency of the requester. In general, outbound components causing holes in aircraft are shipped via the highest priority, and components ordered to fill shelf stock, Closed Loop Aeronautical Maintenance Program (CLAMP) components (which are given special management attention according to their cost, system stock position, or mission essentiality), and most retrograde shipments are given lower priority. Some CLAMP items may be shipped with a high priority. The high priority items are usually sent by air to the deployed carrier, whereas the lower priority items are shipped by surface transportation and low priority air transport. A more complete description of priorities and modes of transport is provided in Ref. 5.

Transportation Performance of the Current Structure

The determination of (peacetime and wartime) transportation times for the CABAL study was the responsibility of the Center for Naval Analyses (CNA); peacetime transportation times are reported in Ref. 5. Table IV-3 shows the range of times for O&ST and retrograde shipment based on the CNA study. These times depend on the type of item, mode of transportation, priority, and theater. Generally, shipments to the Western Pacific and Indian Ocean theaters take longer than shipments to the Mediterranean theater. Based on the CNA results, an average

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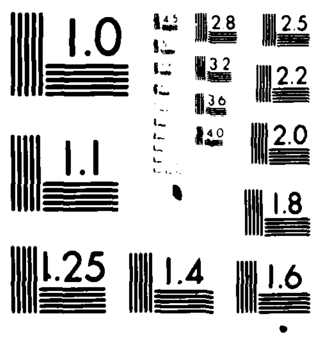

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Table IV-3

RANGE OF OUTBOUND AND RETROGRADE SHIPPING TIMES
(Days)

Operating Area	Outbound	Retrograde
Western Pacific	15-35	40-61
Mediterranean	14-29	40-60
Indian Ocean	23-39	50-65

outbound time of 25 days and average retrograde time of 65 days was used in the analysis. The long times for retrograde shipments (which cover the same distance as outbound shipments) are apparently the result of low priority combined with long holding times (an average of seven days on carriers) before shipment.

The long retrograde times affect the operating forces by tying up AVCAL stocks in transportation pipelines (recall from the supply discussion that no wholesale stocks are currently provided for the retrograde pipeline). Associated with each deployed carrier is about \$290,000 worth of components per day of wartime retrograde shipping time (costs are about half that in peacetime). Thus, about \$12 million worth of components per carrier would be used to cover the additional 40 days of transportation in retrograde beyond the 25 days spent in outbound transport for the set of components considered in this study. That is, if retrograde and O&ST times were the same, approximately \$12 million less in aircraft components would be tied up in transportation.

The CABAL study projected the effect of peacetime (for lack of better information) transportation times on component shortages and aircraft availability in wartime. The effects of transportation interruption were also considered. The previous section showed the performance of the current structure under the current O&ST and retrograde transportation times. An interesting (and perhaps obvious) finding of the study is that reducing retrograde time would have little effect on performance during wartime scenarios lasting less than about 100 days. This is because the total roundtrip time (including depot repair time) for a component would be about 100 days even under the optimistic assumption that retrograde times could be reduced to outbound times. It appears that the primary effect of the longer transportation times is to absorb components, leaving later deployed carriers deficient in AVCAL stocks and ultimately affecting the carrier's ability to maintain a sustained level of effort beyond 100 days.

The long transportation times have important implications for the DRMS alternative of shore repair. The stockage cost to fill 90 days of roundtrip transportation pipeline is so large that it consumes most of the potential economies of scale of a larger shore-based facility. Furthermore, the ability to establish repair priorities at the shore facility would be seriously affected by the remoteness in time from the carrier. Again, had there been other savings by shore repair, the transportation time might have been reduced by expending some of the savings on management and airlift. But this was not the case.

Effect of Transportation Disruption in Wartime

Immediate effects on aircraft availability occur when outbound transportation is disrupted. Figures IV-11 and IV-12 show the effect of a 30-day cutoff of outbound shipments from day 0 of the scenario for two aircraft types. This type and period of cutoff are deemed likely in the event of an intense conflict as higher priority combat material is moved with available airlift. Note that even with full WRA cannibalization to moderate the effects of the cutoff, the effect on aircraft availability is significant, especially when considering that 90 days of self-sufficiency spares are provided in the current AVCAL. The lack of explicit coverage of O&ST and retrograde pipelines means that much of

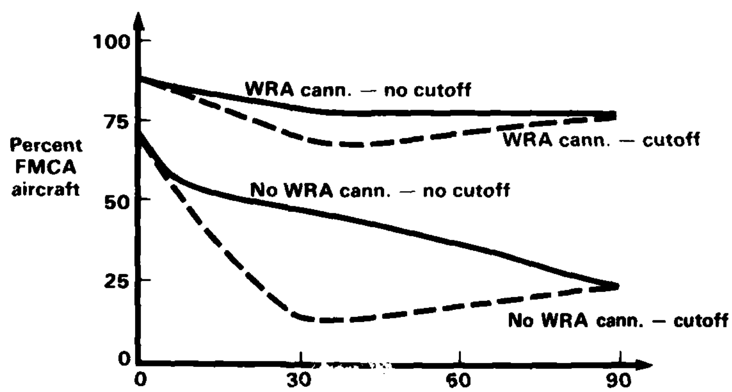

Fig. IV-11—Effect of transpo.tation cutoff for day 0 to 30 on the S-3A avionics availability

this self-sufficiency stock is used up during peacetime flying, so that cutoff from resupply seriously affects performance.

The above findings of the supply and transportation analysis, as well as recommendations for changes in supply and transportation policies that could improve wartime aircraft availability, are summarized in the following chapter.

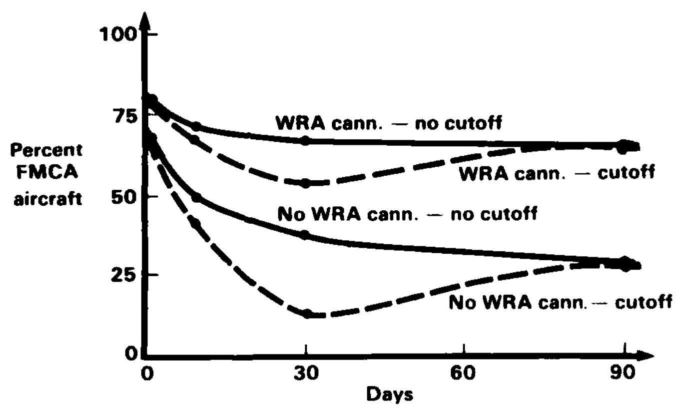

Fig. IV-12—Effect of transportation cutoff for day 0 to 30 on the E-2C avionics availability

V. CONCLUSIONS AND RECOMMENDATIONS

GENERAL

Inadequate performance of any element of the logistics support system for avionics components ultimately results in "holes" in aircraft, which makes it easy (and common) to attribute low aircraft availability to "supply" problems. The interdependence of elements of the system make identification of the real support problem far more difficult than recognizing the symptom that manifests itself as a supply problem. For example, long repair times absorb assets in the maintenance pipeline, reducing the shelf stock available to satisfy customer demands. If the component affected by an extended maintenance cycle is an SRA, the effects of delayed repair may cause increased WRA AWP time, which creates WRA shortages that directly affect aircraft availability. Similarly, extended retrograde transportation times can delay repair induction at the depot. The delay is subsequently reflected first as a wholesale, and finally as a shipboard, asset shortage that degrades aircraft availability.

This interdependence of logistics system elements is implicit in the system description in the Introduction. It was also recognized in the DRMS alternative logistics structure, which was intended to improve aircraft availability. The alternative was motivated by observations that:

- The availability of carrier-based aircraft was low.
- Many non-available aircraft were "down" awaiting spare parts.

- The small scale of carrier-based squadrons limits both the opportunity for cannibalization to alleviate component shortages and the range of parts that could be stocked based on demand.
- An improved transportation and distribution system could reduce the required investment in pipeline spares.
- There was significant slack in the utilization of assigned maintenance resources, particularly manpower, due to low repair demands and fragmentation of resource (skill/test equipment) requirements.
- Low projected resource utilization resulted in proliferation of "one-of-a-kind" skill and test equipment requirements. Loss of one of these critical resources could directly affect aircraft availability.
- If resource utilization could be improved by consolidating repair capability in a shore-based AIMD, the resulting savings could be used to increase asset levels. Further, consolidation of repair requirements could reduce the incidence of AWP, which would help offset the transportation pipeline investment implied by the alternative.

The detailed analysis described in the two previous chapters, however, indicates that the DRMS alternative could not be implemented without significant increases in cost <u>for current aircraft weapon systems</u>. This conclusion was based on several of the major findings of the CABAL analysis:

- <u>No manpower or test equipment savings would result from consolidating carrier workloads at shore-based AIMDS</u>. The apparent savings identified by the DRMS are subsumed by:
  - An increase in 3M-reported AIMD workload
  - Recognition of likely increases in wartime workload (which are <u>not</u> considered in the Navy's manpower requirements methodology)
  - The fact that test equipment for current aircraft is a sunk cost, so no significant economic savings would result from improving its utilization.
- <u>The effects of AWP can be mitigated by including range additives in the AVCAL</u>. These additives, which are not demand-based, are relatively inexpensive but have a large impact on projected aircraft availability.
- <u>Navy retrograde and order/shipping times from the CONUS are exceedingly long</u>. Filling a 90-day pipeline for the assets currently repaired on the carrier would be extremely expensive. While these transportation times appear to be inordinately long--about 90 days for the full ship-depot-ship cycle, excluding depot repair time--the CNA analysis of transportation times did not identify any means of reducing them.
- <u>Priority repair is an extremely powerful tool for coping with temporary resource shortages</u>. Limiting the carrier's repair capability would severely constrain its ability to employ this most important tool.

- <u>The performance improvements contemplated for the DRMS alternative can be achieved through changes in current logistics policies and procedures</u>. These changes are reported, with the findings that support them, by functional area below.

The DRMS alternative, however, should be considered as: (1) a means for alleviating the VAST capacity shortfall identified in Chap. III and (2) an alternative in Level of Repair (LOR) analyses used to establish maintenance policy for future weapon systems. Both of these problems represent cases in which the spares investment needed to fill an off-ship pipeline can be traded off against the costs of providing adequate shipboard repair within the current logistics system structure. A one-time investment in spares pipeline may well turn out to be less than that required for facilities investment. It is even more likely to appear attractive if the alternative is to incur significant recurring costs for manpower that will not be fully utilized.

The remainder of this chapter summarizes the findings and recommendations developed from the analysis described briefly in this report. They are listed by function, because implementing actions must be taken by functional organizations, even though they were generated by an analytic process that considered the interactions between and among functions. These findings and recommendations, and the analysis on which they are based, are described further in the companion volumes to this report [Refs. 1, 3 and 7].

SUMMARY OF FINDINGS AND RECOMMENDATIONS

Manpower

Current manpower requirements are based on peacetime workloads. Increases in workload associated with wartime acceleration of the flying program will overload many avionics work centers.

A manpower requirement based on the total AIMD wartime workload generated from all carrier aircraft would be no larger than the current ACM-02 requirement. The mix of skills, however, would differ significantly and would support the wartime workloads.

No manpower savings would result from consolidating carrier workloads at shore-based AIMDs. Projected manpower utilization rates on board the carrier under the AIMD manning alternative exceed 90 percent for all avionics work centers.

Based on these findings, it is recommended that the Navy base manpower requirements on projected wartime AIMD workloads rather than on peacetime squadron workload. Revisions in personnel management would require Navy policy decisions. Limited analysis favors an alternative that assigns personnel to the AIMD rather than to individual aircraft squadrons.

Test Equipment

VAST does not have sufficient capacity to support the workload generated by a sustained wartime flying program. The effect of this limitation is scenario-dependent. With well-managed priority repair and cannibalization, the VAST can support the flying program for limited

periods of time without severe degradation in aircraft material condition. For longer, sustained scenarios, aircraft availability will decrease dramatically as the backlog increases.

<u>Most other test equipments have low projected wartime utilization</u>. However, no significant cost savings would be realized by centralizing requirements for these equipments since they represent a sunk cost.

These findings suggest that the Navy should <u>explore options to reduce the projected VAST capacity shortfall</u>. Because the magnitude of the VAST problem is scenario-dependent, careful thought should be given to scenario requirements before deciding on ways to reduce the VAST backlog. For example, a reduction in the S-3A wartime flying from programmed rates to those rates used in computing stockage requirements would reduce the VAST capacity requirement from 160 percent to 132 percent. One way to reduce the backlog would be to move all technically feasible SRA repair to other shipboard test equipment; another is to move it to VAST stations at shore-based facilities with excess wartime capacity. A combination of both options is likely to be the least expensive, but if all VAST SRA repair were moved ashore the cost of additional spare parts to cover the transportation pipelines would be about $1.2 million per carrier at the full wartime flying program. With the reduced S-3A flying requirements and the shore repair option, the additional stockage cost would be about $1 million per carrier, with the VAST capacity requirement reduced from 160 percent to 114 percent.

None of the alternatives discussed here bring the VAST capacity requirement down to 100 percent of the available capacity supply. To do so would require moving some WRA repair off VAST, in addition to all SRA

repair, or buying three additional VAST stations. Any reduction in workload, however, will allow for longer periods of sustainability, and therefore decisions on how much reduction is required depends heavily on the scenario to be supported.

The Navy should also maintain test equipment availability data to support the LOR decision process. Since these data are not currently maintained, the Navy may assume that test equipments are available for a large fraction (or all) of their installed time. Such an assumption could have contributed to the current VAST capacity problem. Collecting more accurate data need not imply new data system or routine reporting requirements; the data need can be satisfied by conducting periodic studies of equipment status over relatively short periods of time.

Finally, the Navy should explicitly consider a shore-based repair option for future systems. Purchasing the stock needed to fill transportation pipelines may be less expensive than buying unique test equipments that are not fully used for all of the carriers. Using shore-based Intermediate Maintenance Activities (IMAs) as an option should be considered during the Level of Repair decision process.

Maintenance Management

Local priority repair is an extremely powerful tool that can compensate over limited time horizons for a variety of resource shortages. It can, in effect, shorten repair times for critical items and maintain maximum aircraft availability in the face of short-term resource shortages. Maintenance use of a scheduling rule that explicitly considers the stock position of each item repaired can

concentrate repair capacity on those components most likely to degrade aircraft availability. Hence it is recommended that the Navy support priority repair management explicitly in its continuing development of maintenance management support systems such as NALCOMIS. This would require integrating or interfacing the supply and maintenance data systems to permit supply stock position to be used as the basis for maintenance scheduling decisions.

Supply Range Additives and Cannibalization

AVCAL range additives and SRA cannibalization reduce AWP time significantly and improve aircraft availability. The additives improve availability by increasing the range of components stocked and therefore provide increased protection from demand prediction uncertainty. SRA cannibalization, while important, requires considerable management and an effective maintenance-supply interface.

The S3A availability improvement through range additives and SRA cannibalization is about the same as that predicted for the shore repair alternative in the DRMS. Thus, significant gains can be made within the current logistics structure as a result of changes in stockage policy since the DRMS, additives that were not considered in the DRMS, and the potential to improve AWP times by SRA cannibalization through effective management.

With the AVCAL additives, SRA cannibalization, and current transportation times, few components have AWP times long enough to warrant moving repair ashore. Given no savings in the other resources (such as manpower and test equipment), a constant cost supply analysis indicates that most repair should remain on board the carrier.

Aircraft availability and the amount of cannibalization required are still a problem. Projected cannibalization requirements in wartime to achieve even a 75 percent mission capability rate for avionics components are large for most aircraft types. This finding suggests additional work, loss of flexibility, and that the supply policy is not adequately covering component removal rates, BCM rates, and AIMD repair times.

It is therefore recommended that the Navy emphasize and enhance an effective maintenance-supply interface for SRA cannibalization and AWP management. Data systems such as NALCOMIS should be extended to improve visibility for management of AWP. We also recommend that the Navy examine alternative supply policy options in light of current aircraft availability and cannibalization requirements.

Current AVCAL range additives are important for providing stockage protection against demand estimation uncertainty. The study has shown that additives increase aircraft availability significantly in the current AVCAL and are necessary even when the AVCAL is extended for more complete pipeline coverage. They were not necessary in the optimization technique investigated but that technique was adjusted to obtain a range of stockage equivalent to that provided by the additives.

The extended AVCAL pipeline coverage improves aircraft availability significantly and reduces cannibalization requirements. Additional expenditure for more complete coverage of transportation pipelines with stock safety levels pays off, particularly in the reduction of WRA cannibalization requirements.

A simple optimization method with an aircraft availability objective improves performance and reduces cannibalization requirements compared with either the AVCAL or extended pipeline coverage. For the same dollar expenditure, an optimization technique requiring only slightly more information than the current AVCAL process and using an aircraft availability objective improves performance above that obtained with the fill rate supply objective. With this technique, aircraft availability based on avionics components can reach reasonable levels (when retail and wholesale supply requirements are fully satisfied).

Based on these findings, it is recommended that range additives or other methods of providing an extended range of stockage protection be included in future spares requirements.

In addition, an aircraft availability objective and simplified optimization technique should be considered for use in future modifications of the AVCAL process and for initial outfitting (initial spares procurement for new aircraft).

Finally, collection and use of data for supply requirements should be improved. Since range additives are necessary to overcome forecasting errors in demand and repair estimation and only simple optimization techniques can be proposed because of inaccuracies in configuration data, improving the data collection system should pay off handsomely in improved ability to project spares requirements. Furthermore, since many of the components show very low demand and hence large uncertainty regarding forecasts, statistical techniques (Bayesian techniques, for example) may improve prediction of needs during a deployment.

Transportation

The CNA study indicates that retrograde transportation times are currently very long, causing a large stockage cost and draw-down of total Navy supplies for its carrier aircraft. It also reduces flexibility in shore-based support of carriers. The DRMS shore repair alternative incurs a large cost penalty to fill the long pipelines.

Transportation cutoff, even in the early stages of a conflict, has a serious impact on aircraft availability and indicates that carrier air self-sufficiency is not as great as might be implied by "self-sufficiency" spares. Part of the problem is that outbound and retrograde transportation times are not explicitly considered in the current stockage policy so that even peacetime flying rates draw down the carrier AVCAL supplies significantly.

In view of these findings, the Navy should examine the potential to reduce retrograde times. It appears that large portions of these times are due to management and priority problems rather than to insufficient capacity.

The Navy should also investigate increasing stockage protection against transportation cutoff. This can be done by some of the AVCAL extensions currently under review, including explicit consideration of transportation pipelines and prepositioning of stock needed to cover them aboard the ship. Establishing safety levels for BCM pipelines and adding transportation interruption spares would increase this protection.

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